PROCEEDINGS OF HAZMACON 85

HAZARDOUS MATERIALS MANAGEMENT CONFERENCE AND EXHIBITION

April 23–25, 1985
Oakland, California

ABAG
ASSOCIATION OF BAY AREA GOVERNMENTS

PROCEEDINGS OF HAZMACON 85

Hazardous Materials Management Conference and Exhibition

held on April 23-25, 1985
Oakland, California

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TABLE OF CONTENTS

Page Number

Page
Number

PLANNING

THE DOHS VIEW ON LOCAL HAZARDOUS MATERIALS PROGRAMS

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THE SCOPE OF THE HAZARDOUS MATERIALS PROBLEM

The value of local hazardous materials programs can be best assessed if we first realize the full scope of the hazardous materials problem. In preparing this paper I challenged my staff to find one article in our office, or in their own homes, that did not include an industrial chemical in some stage of its manufacture or use.

We were unable to find a single item.

The food we eat: grown with fertilizers; protected by pesticides, fumigants and preservatives; finally packaged and distributed in paper or plastic manufactured through a chemical process.

The clothes we wear: natural materials bleached or dyed, synthetics manufactured entirely from chemicals.

The car we drive: lead and sulfuric acid in the battery; gasoline in the tank, rubber tires, paint and plastic trim.

The list could be extended indefinitely. Each product that we use at work, at home, in our recreation, has an industrial chemical as a part of its manufacturing process. TSCA[1] lists over fifty thousand industrial chemicals classed as toxic substances. SIC[2] lists more than 150 major industries that use an industrial chemical in their manufactoring process, and produce a hazardous waste from that chemical.

In the nine counties making up our ABAG area there are electroplating industries, fabricated metals, high tech, research facilities, petroleum refineries, the petrochemical industry, automobile manufacturers, and the aero-space industry.

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1 Toxic Substances and Control Act USC 15 Chapter 53 Section 2607(B) 40 CFR 716.7 <u>TSCA Chemical Substances Inventory</u> EPA June, 1980.

2 U.S. Chamber of Commerce <u>Standard Industrial Classification</u> Manual, <u>1980.</u>

This then is the scope of our hazardous materials problem.

The question of "What" is a hazardous material, could more truly be defined as "When". When does an industrial chemical, become a hazardous material, become a hazardous waste? This is the question federal, state, and local hazardous materials programs must answer.

THE MANAGEMENT OF HAZARDOUS MATERIALS

A successful hazardous materials management program falls into three distinct parts: the transportation of hazardous materials; the use and storage of hazardous materials; and finally the treatment, storage, transportation, and disposal of residual hazardous wastes.

Transport

The responsiblity for the safe transport of hazardous materials fall largely to the California Highway Patrol. It is their responsibility to check vehicle, driver, and container.

Each vehicle must be checked for proper maintenance and proper certification, showing that the vehicle has been recently tested and proven safe.

Each driver must be checked to insure he is properly licensed, and registered with the state as a hauler of hazardous materials and hazardous waste. It is especially important that each driver is properly trained to handle hazardous materials, and to react quickly to any emergency such as a rupture, spill, or collision.

Each container must be individually checked and certified to insure it is compatible with the materials being transported, free from leaks, and securely fastened. Each container must be properly labelled with correct DOT[1] hazard class and with warning signs that are clearly visible to all drivers on the highway.

Storage of Hazardous Material

During the second period of hazardous materials management; in that interim of time after the industrial chemical has left the highway, but before it has been used to produce a hazardous waste;

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1 Department of Transportation 49 CFR 173.

oversight of hazardous materials falls largely to local hazardous materials programs. Local officials acting under public safety codes, fire codes, and local hazardous materials ordinances are able to inspect every industry in their area.

Local departments of health in conjunction with local fire departments acting under the Sher Bill[1] can inspect industries storing industrial chemicals in underground storage tanks; local fire departments can check all industries whose use of industrial chemicals might create a fire hazard.

Consider the areas a fire department must check to insure that hazardous materials are properly stored.

I. Containers

(1) Constructed with materials compatible with the substance being stored.

(2) Properly cleaned so that no residue of former material or cleaning agent remains to react with the chemical stored.

(3) In good condition; no leaks, properly vented, properly closed or sealed.

II. Storage area

(1) A safe distance from working machinery that could provide a spark for ignition.

(2) A safe distance from neighboring business or residences.

(3) A safe distance from public right of way so a casually tossed cigarette cannot cause ignition.

(4) An area with proper temperature control--protected from overheating or sudden temperature change.

III. Labeling

(1) Correctly labelled with health, fire, reactivity hazard.

(2) Bi-lingual warning signs posted in clear view.

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1 H&S Division 20 Chapter 6.7

IV. Equipment

(1) Fire extinguishers in working condition, readily accessible, in sufficient number to control a fire, filled with the correct fire retardant.

(2) Respirators or SCBA present and in working condition if the stored chemical is known to generate a toxic gas with combustion.

(3) Alarm system audible over the entire facility area.

V. Mapping

(1) Each chemical in a designated place, stored away from incompatible chemicals.

(2) The location of each alarm signal and extinguisher clearly posted.

(3) An evacuation route for personnel clearly posted.

The local fire department working with the local department of health can have a complete inspection program that will give each local area a complete inventory of chemicals being used within its boundaries.

<u>Use of Hazardous Materials</u>

Any comprehensive hazardous materials program must include worker safety. Each worker using an industrial chemical must be properly trained in that chemical's use, storage, and proper disposal. Each worker must be fully informed of the health dangers of any chemical he uses. He must be given protective clothing, be monitored for exposure time and exposure concentration, and work in an area that is properly ventilated to protect him from hazardous fumes. His workplace should provide immediate access to first aid, emergency showers and eyewash. The chemical that he uses must have proper warning labels and have a complete Material Safety Data Sheet which each worker must be trained to read and understand.

Worker safety while using hazardous materials is a state responsibility regulated by Cal-OSHA,[1] but each local hospital must have the necessary emergency equipment and training to treat chemical injuries and chemical exposure.

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1 Cal-OSHA Title 8 GISO

THE ROLE OF DOHS-TOXIC SUBSTANCES CONTROL DIVISION

It is the responsibility of DOHS-TSCD to protect public and environment against the dangers of hazardous waste. The inspection, enforcement, permitting and site mitigation activities of TSCD form a complement to local hazardous materials programs, and working together we have an opportunity to provide the much talked about "Cradle-To-Grave system of hazardous materials management.

Treatment, Storage, and Disposal

The moment a material becomes a "waste" material, and the moment a hazardous material becomes a "Hazardous Waste" are clearly defined by both state and federal law.

I. "Waste" means either of the following[1]:

(a) Any material for which no use or reuse is intended and which is to be discarded.

(b) Any recyclable material.

II. "Hazardous Waste" means a waste or a combination of wastes which because of its quality,[2] concentration, or physical, chemical, or infectious characteristics may either:

(a) Cause or significantly contribute to an increase in mortality or an increase in a serious irreversible, or incapacitating reversible illness.

(b) Pose a substantial present or potential hazard to human health or environment when improperly treated, stored, transported, disposed of, or otherwise managed.

The scope covered by the hazardous waste laws includes[3]:

(a) Except as provided in Section 66300(b) (Radio-active wastes), 66300 (g) (Household hazardous wastes), or 66310 (Variances) all provisions of this chapter shall apply to the management of any liquid, semi-solid, solid, or gaseous waste which conforms to the definition of hazardous waste in Section 25117 of the Health and Safety code including but not limited to the following:

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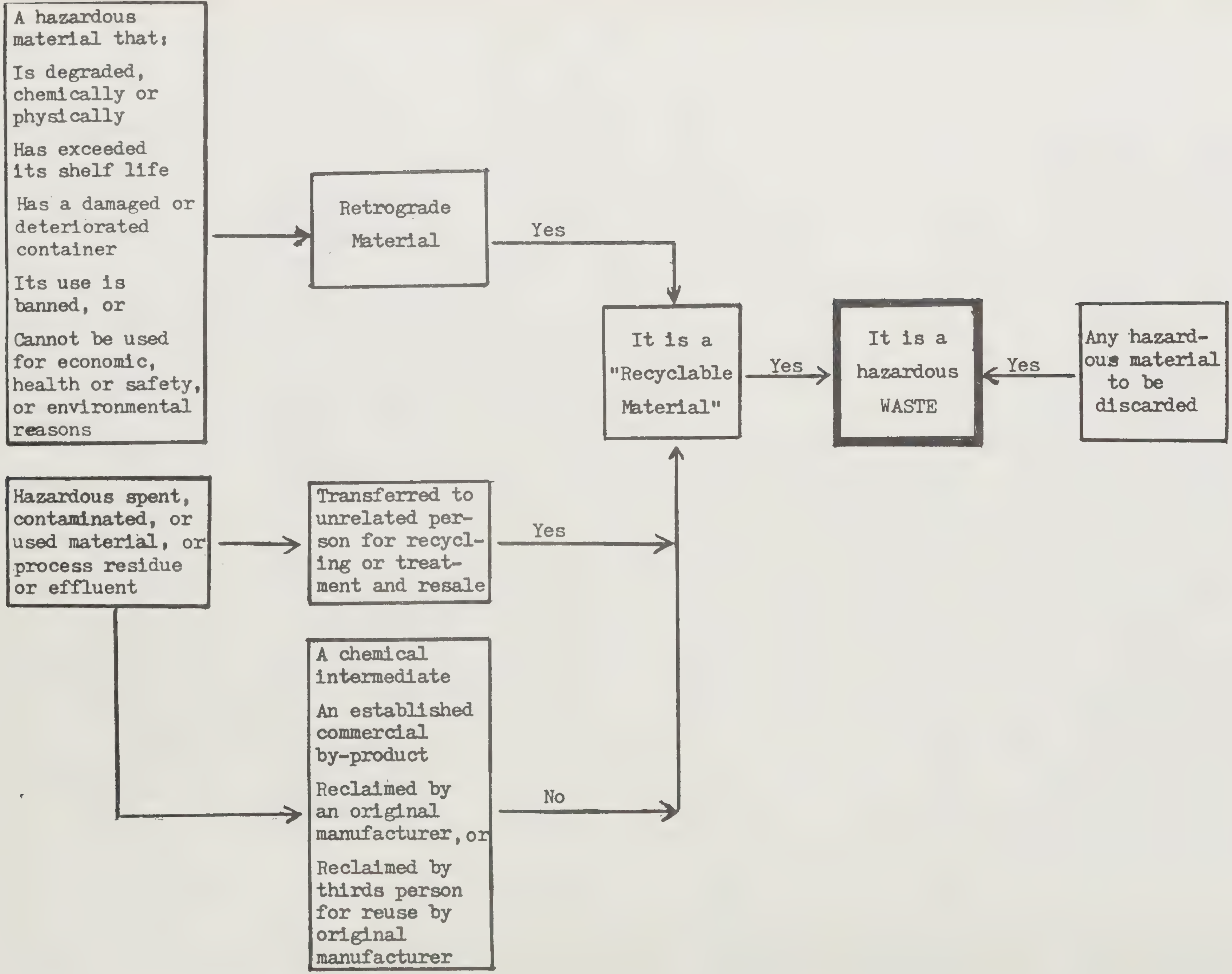
1 H&S Division 20 Chapter 6.5 Section 25122
2 H&S Division 20 Chapter 6.5 Section 25117
3 CAC Title 22 Division 4 Chapter 30 Section 66300



(Definition of a hazardous waste pursuant to Sections 25121.5, 25122, and 25122.5, Health and Safety Code)

(1) Waste which is hazardous pursuant to any criterion in Article 11 of this Chapter, and consists of or contains a hazardous material cited in Article 9 of this Chapter, or is a hazardous sludge residue, concentrate, leachate or ash orginating from a waste.

(2) A waste mixture formed by mixing any waste or substance with a hazardous waste.

(3) Hazardous material disposed of to land or water, accidently discharged onto land or water, or accidently spilled onto land or water.

(4) Leachate from a hazardous waste (see figure 1).

Permitting

The issuing of permits provides permanent guidelines for the proper treatment, storage and disposal of hazardous wastes. There are at present 342 TSD facilities in our area. Thirty seven of these are major facilities having land disposal or incineration as the method of final disposal. All of these facilities are at present operating under Interim Status Documents (ISD facilities.)

It is the task of TSCD Permitting Unit to inspect each of these facilities and to completely review all their operations plans to insure each facility meets all federal and state requirements for land disposal. It can take from two to five years for a major facility to be granted a full permit, and it is the goal of TSCD to have all these facilities fully permitted within another three years. All major facilities in our area are inspected at least once a year, and the major land disposal facilities are inspected quarterly.

Surveillance and Enforcement

A second responsibility of TSCD is to inspect each generator and transporter of hazardous wastes in our area. When necessary TSCD works with City Attorneys, District Attorneys, or the Attorney General to bring enforcement action against generators and transporters to bring them into compliance with the hazardous waste laws.

So far this year 140 cases have been opened in California, 35 cases settled, and $451,000 assessed in fines and penalties.

While it is the responsibility of the CHP to verify safety, registration, and certification of hazardous waste haulers, TSCD must insure that all hazardous wastes reach the final disposal destination within 96 hours of being picked up, and are not being illegally stored. TSCD inspects all manifests to make certain generator, transporter and TSD have accurately accounted for all wastes produced.

There are at present 1,650 transporters of hazardous waste registered in California, 275 in the ABAG area.

There are more than 17,000 generators of hazardous waste now registered in California, 3,300 in the ABAG area. These are RCRA[1] generators, listed by the EPA as producing more than 1000 kilograms of hazardous waste each month.

When RCRA was first enacted in 1976 it was thought that by regulating only the large quantity generators (approximately 15-25% of all hazardous waste generators) 75-80% of all hazardous waste produced would fall under RCRA regulation.[2] This has not proven to be the case, so when RCRA was reauthorized in November of 1984 it was decided all generators producing more than 100 kilograms/month (approximately one-half of a 55 gallon drum) should fall under the RCRA program, and be given a yearly inspection to insure compliance with hazardous waste laws.

If the original estimate is accurate and only 20% of the actual generators are now listed, a rough estimate shows there are more than 85,000 generators in the State of California; 16,500 in the ABAG area alone, waiting to be indentified, inspected, and brought into compliance with state and federal hazardous waste laws.

Given the broad scope of this mandate DOHS-TSCD and local departments of health have found mutually advantageous to establish cooperative hazardous waste programs. The Health and Safety Code[3] provides:

> "The standards and regulations adopted by the Department pursuant to Section 25150 shall be enforced by the Department or any local health officer or any local public officer as designated by the director."

The formal means of delegating this power to local officials has become known as a Memorandum of Understanding (MOU). Under an MOU agreement each County Department of Health takes the responsibility for inspection of generators and transporters in its own area. Each county program is antonomous and remains entirely under local control. The county hires its own inspectors and is able to set a program of licensing and inspection fees which can entirely offset the costs of the hazardous waste program.

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1 RCRA 40 CFR Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act of 1976 as amended 42 USC Section 6901 et seq.

2 EPA Questions and Answers on Hazardous Waste Regulations SW-853, 1980.

3 H&S Division 20 Chapter 6.5 Section 25180.

DOHS-TSCD by law retains all permitting, and all inspection and enforcement activities for Permitted or ISD facilities.

To encourage the development of local hazardous waste programs TSCD provides each MOU county with access to state training programs. Examples of training programs which will be provided this year include:

(1) Hazardous Appraisal Recognition Planning (HARP)

(2) Respirators: Air Purifying and Self Contained Breathing Apparatus (A/P and SCBA).

(3) First Aid/CPR

(4) Instrumentation and Field Sampling

(5) Confined Space Entry/Toxicology

(6) Generator inspection training

(7) Transporter Inspections

(8) Local Household Hazardous Waste Programs

The Berkeley office also provides an apprentice program whereby new county inspectors can be given individual training in inspection procedures, and carrying our enforcement activities.

When samples are needed for enforcement cases, state and county inspectors make a joint inspection, and state laboratory facilities are made available to the counties on an enforcement priority basis.

In any enforcement action there is a need for constant communication and coordination of activities between state and local DOHS, and state and local enforcement agencies.

An MOU agreement particularly advantageous to the county in terms of enforcement cases. The Health and Safety Code provides[1]:

"All criminal and civil penalties collected pursuant to this chapter shall be apportioned in the following manner":

(1) 50% shall be deposited in the Hazardous Waste Control Account in the general fund;

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1 H&S Division 20 Chapter 6.5 Section 25192

(2) 25% shall be paid to the office of the City Attorney, District Attorney, or Attorney General, whichever office bought the action;

(3) 25% shall be paid to the Department and used to fund the activity of the local health officers to enforce the provisions of this chapter.

It takes equal time and effort to prepare a case under local hazardous matrial ordinances, fire and safety codes, fish and games laws, or even unfair business practices. The difference is that in these cases the penalties range from $50-2,500. Cases successfully prosecuted under the Hazardous Waste Laws can bring penalties of $25,000 per day, per violation.

Local MOU programs bring more than monetary benefits to the counties and to TSCD. Generators inspected under the hazardous waste laws are required by law to have a full Contingency Plan and Emergency Procedures Plan. Copies of these plans must be filed with the nearest local police station, the nearest local hospital, and the nearest local fire department. Thus in the case of any emergency, police, fire, and hospital should have some knowledge of the chemicals involved, how many people and how wide an area are likely to be involved, what emergency equipment and emergency treatment will be required, how much time they will have to respond, and how much time they will have to evacuate an area should that become necessary.

Local programs have the ability to put more trained inspectors into the field, and subsequently can make contacts with the expanded universe of generators and transporter. Local inspectors bring to a hazardous waste program a specific knowledge of local industry, local geography, and local site conditions that no state or federal program can match.

Working together TSCD, local departments of health, and other agencies working under local hazardous materials ordinances can provide a comprehensive program of inspection and enforcement over many aspects of hazardous material and hazardous waste management.

The use of industrial chemicals is an inherent part of this 20th century society. Effective hazardous materials programs will help insure that industrial chemicals remain a useful industrial material, and do not become hazardous wastes by virtue of accidental discharge, neglect or mismanagement.

STATUS OF HAZARDOUS MATERIALS PLANNING
IN CALIFORNIA COUNTIES

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Abstract: At present thirty one counties have hazardous materials response or contingency plans. These plans are developed within the framework of existing emergency response procedures and state and federal response plans. The scope of existing county hazardous materials plans varies widely. Based on OES review of these plans and the state and federal plans, a number of elements that combine to make up a good plan can be identified. All response plans should be reviewed, and if necessary, revised on a regular basis.

Two types of hazardous materials planning are being done in California. Comprehensive hazardous materials management plans - covering all aspects of hazardous materials production, use, storage, transportation, and disposal in the community - are being done in many cities and counties. More common, however, are hazardous material response or contingency plans. At present thirty one (31) counties, and numerous cities, have formal hazardous material contingency plans.

As with other types of emergency response plans, local governments submit copies of their hazardous material contingency plans to the State Office of Emergency Services (OES) for review. OES reviews these plans in the context of the overall response system, including state and federal responsibilities. This paper will outline several items that contribute to a good hazardous material contingency plan.

Framework for Local Planning

Hazardous material incident response builds upon other emergency response procedures; local government is responsible for handling an incident that occurs within its jurisdiction. Local government may, of course, access resources from other levels of government when its are unavailable or completely committed or when specialized resources are needed. Cities, for example, may access resources from other cities, the county, or the state or federal government. These specialized or additional resources should be accessed through procedures outlined in these other jurisdiction's plans.

Local plans should be developed in recognition of these other levels of planning in order to provide for efficient access to response assistance and resources. In OES' review of local plans, attention to state and federal plan procedures is important. The California Hazardous Material Incident Contingency Plan identifies state agency roles and responsibilities, outlines the state scene management system, and sets out notification procedures. The National Contingency Plan outlines response procedures in response to oil and hazardous substance spills and procedures for evaluating removal and remedial incidents. Both plans rely on the local agency to provide the state or federal government with timely notification of the occurance of an incident, an accurate description of the incident, and a clear request for the resources that are needed.

Key roles are identified in the state and federal plans that should be referenced in local plans. The State Agency Coordinator and Federal On Scene Coordinator represent the key points of contact between the local scene manager and state and federal agencies. It is encouraging to see references to these roles in local plans because it represents a local understanding of how the larger system works.

Advisory Committees

The state plan suggests that local hazardous material planning activities be carried out with the assistance of Hazardous Material Planning Advisory Committees. These committees can assist the local agency charged with plan development in resource identification, hazard assessment, local agency role and responsibility definition, and contact with other elements of the community's hazardous material program, among other activities.

Committees should represent a cross-section of community interest in hazardous material incident response. All key local agencies should be involved, including both county agencies (such as fire, sheriff, environmental health, emergency services, and agricultural commissioner) and city agencies (fire, police, and public works, for example). Local representatives of state agencies (including Highway Patrol, Fish and Game, Regional Water Quality Control Boards) and federal agencies (such as the Coast Guard District or the Forest Service in some inland areas) should be invited to participate. Local hazardous material manufacturers, users, transporters, and hazardous waste managers could be valuable contributions to the committee. Local utilities, school districts, Red Cross, League of Women Voters, university or other interested parties may also be asked to participate.

At the latest survey about fifteen counties have designated hazardous materials advisory committees although other counties use other emergency planning groups to perform a similar function. Several counties - Solano, Santa Clara, and San Bernardino, for example - are currently using advisory committees to revise their county plans. Other counties, San Mateo County and the Bay Area Industrial Council is an excellent example, use advisory committees to guide not only planning but development and implementation of their whole hazardous materials response program.

Scope of Existing Plans

Thirty one counties have some sort of hazardous material response or contingency plan. These include most San Francisco Bay Area counties, those in the Los Angeles/San Diego areas, the coastal areas in between, and major Central Valley counties. The plans vary widely in quality, age, and scope. Some are extremely comprehensive, outlining response procedures in great detail, and others are merely a sketch. Virtually all of the plans have been developed since 1981 and most since 1983. Some cover just transportation incidents (intentionally or unintentionally), others cover all types of incidents, and a few cover just a specific chemical accident (such as a chlorine release).

The geographic area covered by a county plan may also vary. Most common are plans that cover just the unincorporated area. Some, such as those of San Diego, Fresno, and San Mateo Counties, cover all or most of the cities within the county as well. Other counties, such as San Luis Obispo and Riverside, provide their adopted plans to cities in the county for their use as a model. Finally, some cities have developed their own comprehensive response plans which then need to be coordinated with the county's plan.

Plan Elements

Plans submitted to OES are reviewed. There are no firm guidelines for review of local hazardous material contingency plans. The following examples of what makes up a good contingency plan are garnered from review of existing plans.

1. The plan should contain comprehensive definitions of "hazardous materials" and "incident". The plan should be broad enough to cover all anticipated events. Are spills of deleterious materials, those that may not threaten human health and safety but may cause severe environmental consequences, included within the definition of hazardous materials? Does the plan address incidents at fixed facilities or "midnight dumping" as well as transportation incidents? Does the plan cover an "emergency" that may not be an accidental spill or release (e.g., a legitimate pesticide application in adverse meterological conditions)?

2. Appropriate notification procedures must be spelled out. A central point of contact should be designated. In current plans this point takes many forms, such as a Sheriff's dispatch, central fire communications, Highway Patrol (by agreement during the planning process), or County Emergency Services/County Communications Center. The plan should outline which local agencies are to be contacted in specific circumstances, either by containing this information in the plan or referencing other procedures or checklists. It should also designate who is responsible for deciding which agencies are contacted (the scene manager, dispatcher or other person). The plan should also indicate that OES and/or the Highway Patrol should be notified of any significant incident. (Parameters are outlined in the State Plan.) Responsibility for requesting and making this notification should be identified.

3. Scene management responsibilities for on and off-highway incidents must be assigned. State law gives on-highway responsibilities to the law enforcement agency with traffic jurisdiction but local government must designate off-highway responsibilities. In about two-thirds of the plans reviewed, this off-highway responsibility is assigned to the fire agency; the other third have assigned it to local law enforcement. Some plans have also opted to designate a third type of scene manager, one for the cleanup phase of incident response or for long term or non-emergency incidents. This responsibility is generally assigned to the county environmental health or public works department.

4. The plan should identify a response system. How will the scene manager interact with other responders? Two common models are the Incident Command System, in common usage in the fire service, or the State Scene Management System, outlined in the State Plan. Some plans spell the response system out in great detail, others incorporate it by reference. The former may have advantages, particularly for those agencies that participate in hazardous material incident response that may not be used to responding as part of a formal command system.

5. Local agency roles and responsibilities must be defined. This may be done by agency, defining the activities to be undertaken by law enforcement, fire, environmental health, public works, agricultural commissioner, and other agencies. Or it may be done by responsibility, spelling out who has roles in notification, identification, containment, crowd control, public information, evacuation, and other actitities. A matrix combining the two approaches has been useful to many counties.

6. State and federal agency roles should be recognized in the plan. State Agency Coordinator and Federal On Scene Coordinator roles, and the agencies likely to fill the roles, should be identified. The impact of having state and/or federal agency representatives on scene and the relationship of those responders to the scene manager should be discussed. When pre-emption of scene manager responsibilities by state or federal representatives occurs should be accurately described. The plan must spell out the importance of obtaining pre-authorization for access to state and federal Superfunds. These and other resources can only be made available if the state or federal government knows about an incident in an accurate and timely manner.

7. The plan should include listings of local resources. This can be done through a resource directory that is an appendix to the plan or it may be on a computer or in a card file. It should include local and regional Hazardous Material Response Teams and other public agency physical, financial, and technical resources. It should also include how to access private resources such as cleanup contractors, heavy equipment operators, local chemists, and food supplies, including after hours contacts and payment procedures.

Plan Revisions

Many of the current plans are or will soon be undergoing revision and updating. These plans should be updated to reflect the availability of new resources (such as a local hazardous material response team) or redefinition of agency roles and responsibilities. It may also be revised in response to critiques of plan exercises or real incidents. In any event, plans should be reviewed and, if necessary, revised at established intervals and exercised regularly.

OES and other state and federal agencies involved in hazardous materials incident planning and response should be ready to assist local agencies in the development of their local plans.

THE ROLE OF LOCAL PLANNING IN HAZARDOUS MATERIALS MANAGEMENT

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Introduction

Planners are generalists and their expertise is not usually considered relevant to technically rigorous fields such those represented at HAZMACON. The involvement of planners in the area of hazardous materials has, for the most part, been limited to processing of permits for generators and disposers. Nevertheless, I believe that we planners can have a more positive and productive role in hazardous materials management.

In the keynote address on Tuesday, John Wise of EPA emphasized the importance of local government in solving hazardous materials problems. We have also heard references to a frightened and distrustful public -- distrustful not only of industry, but of government as well. I don't believe this fear and distrust can be easily abated, but I do believe that positive problem-solving moves on the part of local government can help.

I'm sure you're all very much aware of the large number of constantly changing programs and regulations, existing at all levels of government, dealing with the use, handling and disposal of hazardous materials. These programs are often confusing, overlapping and contradictory -- especially at the local level where effects of federal and state programs are ultimately felt.

Despite the many state and federal programs, there is significant scope and a real need, for local programs. Local fire, police and health personnel must plan for and respond to emergencies. There is also a significant role available in terms of land use planning -- not only in siting of disposal facilities, but also in siting and regulating of businesses and industries which produce, handle and dispose of hazardous materials.

Solano County Approach to Hazardous Materials Planning

Solano County has attempted to bring all of these local

concerns together in one policy document, intended to guide the efforts of County and city governments in coping with hazardous materials. Other local governments have taken similar approaches. I will go into some detail on the Solano County plan as one example of what can be done.

The Solano County plan has been treated as an element of the County's Solid Waste Management Plan. Solid Waste Plans are required for each California County under State law. They must be adopted by the County Board of Supervisors, and by a majority of the cities with a majority of the county population. Solid Waste Management Plans must be updated every three years, and were, until recently, required to include "a program for the handling and disposal of special and hazardous wastes."

Solano County began work on its first Solid Waste Plan update in 1981. At the time, the State Department of Health Services was recommending that counties prepare full-fledged hazardous waste plans, consistent with draft guidelines issued by the Department.

Our County is a relatively small producer of hazardous wastes -- we produce roughly 3% of the total in the San Francisco Bay area -- but local awareness of hazardous materials problems is fairly high, due to the volume of such materials which pass over the County's freeways, and also due to the presence of a Class I hazardous waste disposal site and three Class II-1 sites within the County boundaries.

With these points in mind, the County took the opportunity to formulate official County policy on the issues involved. The Solid Waste Management Plan was an ideal vehicle for this policy since it is adopted not only by the Board of Supervisors, but also by a majority of the city councils in the County, thus lending more weight to its policies.

The stated goal of Solano County's Hazardous Waste Management Element is to:

> Protect public health and the environment by providing for the safe and effective management of hazardous wastes produced, transported and disposed in Solano County.

This goal is supported by eight objectives intended to direct efforts to attain the goal. These objectives include:

- o First of all, ensuring that the management of hazardous wastes conforms to applicable state and federal laws and regulations.
- o Secondly, ensuring maintenance of appropriate land uses adjacent to hazardous waste generating and disposal facilities, and providing for appropriate siting of new facilities.
- o Third, promoting the development and implementation of effective local spill prevention programs.
- o Fourth, providing adequate disposal facilities for hazardous wastes produced in the County.
- o Fifth, promoting hazardous waste reduction by generating industries.
- o Sixth, encouraging the development of safe alternatives to land disposal of hazardous wastes.
- o Seventh, encouraging regional planning for hazardous waste management.
- o Eighth, ensuring effective response capability for spills and other emergencies related to hazardous materials.

Plan Development

Now I would like to backtrack a little and tell you how we developed the plan.

Consistent with the Department of Health Services (DOHS) guidelines, the Plan set out to define and quantify both hazardous wastes generated in the County and hazardous wastes disposed in the County. As most of you probably can guess, this turned out to be a nearly impossible task.

The several disposal sites in the County willingly provided types and quantifies of wastes disposed. In many cases, however, various wastes were lumped together in broad and ill-defined categories. In attempting to define the

types of wastes more closely, we discovered that several classification systems existed and correlations between them were poor.

Attempting to define and quantify wastes produced proved even more difficult. The state's system of shipping manifests for wastes disposed offsite was in effect at the time, but results were available for such a short period that it was very uncertain whether they represented a true picture over a longer period.

Data for wastes going to onsite disposal were even more sketchy. Early reporting to EPA under RCRA was of questionable accuracy and not all industries had responded. Finally we resorted to the commonly accepted rule-of-thumb that onsite disposal quantities are four times as high as offsite disposal quantities. Types of wastes being disposed onsite were impossible to ascertain.

Needless to say, the final Hazardous Waste Plan called for development of improved information on the County waste stream in order to allow more effective planning.

The County Plan also attempts to project quantities in the waste stream until the year 2000, using percentage estimates developed by DOHS based on anticipated industrial growth. These numbers are very much open to question, however, as they may be affected by changes in the economy, changes in technology, changes in regulations and the potential development of a major industrial area along the Sacramento River in Solano County.

The County Plan also discussed the functions of state, federal and local agencies dealing with hazardous wastes took a look at potential regulatory changes which could have significant effects on future planning, and discussed in some detail the operations of existing hazardous waste disposal sites in the County.

As a result of all these investigations the County identified a number of issue areas to be considered in developing its implementation plan. These included:

Data base problems.
Future availability of disposal facilities.
Siting of disposal facilities.
Compatibility of adjacent land uses.
The planned ban on land disposal of some hazardous wastes.
Rising disposal costs.

Regulation and enforcement.
Abandoned sites, and
Hazardous materials emergencies.

Alternative plan proposals were then formulated and the measures to be included in the final implementation plan were selected from these alternatives.

Since the County already has a number of hazardous waste disposal sites, finding new sites was not a plan priority. Abandoned sites were not a significant problem either, since most of the County is, and has been, farmland.

The County _is_ growing rapidly, however, and as a consequence, the final plan gives most of its attention to measures designed to cope with increases in locally-generated hazardous wastes and attendant increases in spill potential.

Program for Hazardous Materials Management

Consistent with the overall Solid Waste Management Plan, the Hazardous Waste Element sets forth short, medium and long term plans consisting of groups of implementation measures.

The Short Term Plan covers a 3-year period from 1982 to 1985. The first implementation measure in the short term plan is the "adoption of general plan policies and zoning regulations pertaining to siting and buffering of hazardous waste facilities." Facilities, in this case, include generating facilities as well as storage and disposal operations. The measure calls for County health, planning and emergency services staff, in consultation with city staffs, to examine available information to assess the health and environmental risks associated with both existing and potential future facilities, and to establish siting and buffer area criteria for these facilities. Cities and the County should then use these criteria to formulate and adopt general plan policies and zoning regulations to guide siting, buffering and conditions of approval for facilities.

The second short term measure is to require approved spill prevention programs for new development projects which handle hazardous materials.

The third measure calls for the County to promote consideration and adoption of community "right-to-know" ordinances. Most of you are probably familiar with these ordinances which require disclosure of information regarding

types, locations and health effects of hazardous materials on business premises. Individual ordinances vary from those which require disclosure to the general public to those which require very limited disclosure to designated emergency services personnel.

The fourth short term measure calls for the County to support regional planning for hazardous waste disposal. It points out that the San Francisco Bay Area is a major hazardous waste generating region, with concentrations of generators in Contra Costa, Alameda, Santa Clara and Sonoma Counties. Disposal facilities, on the other hand, are concentrated in northern Contra Costa and southern Solano Counties. There is a need for better distribution of disposal facilities to shorten haul distances and better serve the area. Disposal facilities to be sited should include--and, as a practical matter will probably be limited to--those using alternative technologies to avoid land disposal.

The fifth measure would establish an interagency committee to plan for hazardous materials emergencies and to coordinate response capabilities, mutual aid, personnel training and other areas.

The sixth measure calls for updating of the County's badly outdated 1976 Hazardous Spills Emergency Response Plan. The seventh measure calls for training of personnel to respond to hazardous materials emergencies.

The Medium Term Plan covers the time period 1986-1990. The first measure in this period anticipates full implementation of state and federal permit programs which will, in turn, provide much of the base data needed by local agencies for adequate emergency response planning, land use planning, and hazardous waste management planning.

The second measure calls for reassessment of drilling mud disposal needs, since it is anticipated that existing county sites may be full between 1990 and 2000. A new site is to be identified if necessary.

The third measure calls for cities and the County to assess local transportation risks and establish designated routes or hours for hazardous material hauling if necessary. A fourth measure calls for outreach assistance to small businesses which may handle small amounts of hazardous materials and which may be poorly informed as to proper handling and disposal.

The Long Term Plan, from 1991 to 2000, includes just one implementation measure -- the establishment of a HAZMAT Response Team if needed in the County by that time.

Progress Toward Plan Implementation

The revision of Solano County's Solid Waste Management Plan, including the new Hazardous Waste Management Element, was finally adopted by the Board of Supervisors in November 1983, following adoption by six of the seven cities in the County. At about the same time, the Board of Supervisors approved the consolidation of planning and environmental health staffs into a new Department of Environmental Management. This fortuitous combination of events has provided the County with a uniquely appropriate agency for carrying out the Hazardous Waste Plan.

At this point there is just one problem with this approach... after a year and a half, the planning and environmental health staffs are still in separate offices in separate cities, about 15 miles apart. Often-stalled plans to relocate them to one office may be realized in a few months. In the meantime, the first implementation measure, relating to general plans and zoning, has not been undertaken.

Progress is being made on other measures called for in the Plan. Environmental Health staff is negotiating a memorandum of understanding (MOU) with the state which will allow the County to assume authority for inspecting hazardous waste generating facilities. This will assist with implementation of the medium term measure to complete implementation of state and federal programs, and will also allow the County to implement a small business assistance program.

Require spill prevention programs. The County currently requires spill prevention programs for unincorporated area development projects and may be able to do so in cities when the MOU with the state is approved.

Right-to-know ordinances. Three of the seven cities now have "right-to-know" ordinances and a fourth is working toward adoption. These generally call for disclosure of hazardous materials information to fire departments. Environmental Health staff plans to use information developed through these ordinances, and through the generator-inspection program, to set up a countywide file for emergency use.

Regional planning. Solano County continues to support programs leading toward regional solutions to hazardous materials problems. My being here today is one example of such support.

Interagency committee. The Board of Supervisors has appointed a Hazardous Materials Advisory Council composed of staff from local, state and federal agencies, and private industries, which have involvement with hazardous materials in the County. The Council has been meeting for about a year and has made progress in several areas, although the problems of coordination have proven to be both difficult and complex.

The Hazardous Spills Response Plan is slated for updating by the County's new Director of Emergency Services, but it has not been accomplished as yet.

Hazardous materials training is the focus of ongoing efforts by the Advisory Council which is working to establish a program tailored to local needs, through the community college. In the meantime, much has been accomplished through individual efforts of local fire departments and the Highway Patrol.

Some moves have been made, as I mentioned, toward implementation of the Medium Term Plan. The proposed MOU with the state will assist with two of the measures. Reassessment of drilling mud disposal needs has not begun and need for routing regulations is not anticipated for most of the County in the near future.

Implementation of the Long Term Plan has already been begun by the Hazardous Materials Advisory Council which has applied for funds to equip various city and county vehicles for response to hazardous materials emergencies.

Conclusion

Solano County's Hazardous Waste Management Element was developed with input from planning, environmental health and emergency services staff. It takes an overall look at hazardous materials issues and concerns in the County and provides a comprehensive program for dealing with them. It includes emergency prevention as well as emergency response. (Prevention, in this case, includes good land use planning.)

Perhaps the greatest strength of the County's Plan is that it is countywide policy adopted by decisionmakers of both the cities and the County government. As such, it

ends a clear message to the public that its elected representatives are protecting the interests of the County and its citizens in a responsible way. It also gives direction and support to city and county emergency services, health and planning staffs in their efforts to deal with the difficult problems of managing hazardous materials. The provision in state law requiring regular updating of the Solid Waste Plan should help to keep the Hazardous Waste Plan current in an area where change is a constant.

Reference

Solano County Solid Waste Management Plan Revision. Solano County, Fairfield, November 1983.

KH/lw

LOCAL HAZARDOUS MATERIALS PROGRAMS
A CRUCIAL NEED IN SEARCH FOR EFFECTIVE IMPLEMENTATION

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ABSTRACT

The interest of local Health Departments to develop comprehensive hazardous materials management programs in their respective counties, was triggered by the public's demands for the protection of public health and the environment from the impacts of Hazardous Substances. The Federal and State Agencies have promulgated volumes of standards and regulations, but cannot provide effective public health protections for employees and residents of local jurisdictions. Now the questions develops, would the local health programs run away from this awesome responsibility, namely, protecting the public health of local residents? Or shall we take charge of our responsibility to protect the public health and the environment? This paper represents a plan to establish a local Hazardous Materials/Waste Management Program. The plan identifies the purpose, objectives and needs for such programs. The major ten elements of a local program are presented in this plan. The advantage of such a plan, is that local Health Agencies will meet their mandates, protect the public health; acquire the necessary visibility and leadership expected of them.

I. STATEMENT OF PURPOSE

The purpose of the program is to evaluate and manage the hazardous materials/waste in a local County.

The plan should document the available data on hazardous waste generators, haulers, and on-site and off-site disposers. The plan should evaluate the existing level and adequacy of enforcement provided by Federal, State and local agencies to manage the hazardous materials/waste in a County. The plan should also identify the legal mandates for the management of hazardous materials/waste and the authority delegated to local government. Finally, a plan of action, compatible with the needs of the people of the County as expressed by members of Community and business agencies such as County Grand Jury, League of Women Voters, Board of Supervisors, League of Industrial Association, etc.

In its entirety, the plan should take into consideration, the legal and ethical commitment of local government to extend public protection for the people of the County and for the preservation of a balanced, healthy environment.

II. IDENTIFYING THE NEED FOR A LOCAL PROGRAM

1. Identify the number of hazardous waste generators in the County.
2. Identify the number of facilities handling hazardous substance.
3. Identify the number of registered hazardous waste haulers.
4. Identify the number of hazardous waste treatment, disposal and storage facilities permitted by the State Department of Health Services in the County.
5. Identify the number of known potential hazardous waste properties in the County.
6. Evaluate the number of incidences of hazardous materials spills and releases to the environment in the County and compare with other Counties and State averages.
7. Compile and compare statistics of work related injuries and occupational diseases in the local County and establish trends.
8. Evaluate Federal, State and local agencies' performance records and establish the levels of surveillance and enforcement of the hazardous materials/waste management laws

and regulations.

We believe that the elements, diversity and work load of a local hazardous materials/waste management program should reflect the real needs established in items one to eight above.

III. PROGRAM OBJECTIVES

1. To inspect, evaluate and maintain an adequate surveillance of hazardous waste generators, on-site and off-site disposal facilities, and haulers in the County in order to ensure full compliance with all applicable laws and regulations for the handling, storage, transportation and disposal of hazardous wastes.
2. To investigate all complaints and take corrective action, as necessary, against any person or entity who disposes of hazardous waste in violation of existing law.
3. To provide consultation, education and training to industries and residents of the County in the proper procedures and the legal requirements for safe handling and disposal of hazardous waste.
4. To interface the legal, administrative and technological aspects of hazardous materials/waste with the land-use planning process in the cities and unincorporated areas of the County in order to ensure a compatible land-use development.

IV. ACTIVITIES

1. Conduct inspections of all hazardous waste haulers to assure their compliance with applicable laws and regulations.
2. Conduct inspections of the hazardous waste generators to assure the safe handling, storage, and disposal of hazardous waste on their premises.
3. Conduct periodic inspections of on-site and off-site hazardous waste disposal facilities to assure compliance with applicable laws and regulations.
4. Initiate corrective and enforcement action against establishments in which violations of hazardous waste laws were observed.
5. Conduct an inventory inspection of all hazardous waste generating facilities in the County, to compile information concerning the types and quantities of hazardous wastes produced, and

the manner in which these wastes are being hauled and disposed of. A data bank with information from all hazardous waste generating businesses in the County should be established.

6. Develop a coordination plan with the State Department of Health Services, State Water Quality Control Board, Bay Area Air Quality Management District, County Public Works, Planning Agriculture and Office of Emergency Services to facilitate information sharing and to avoid duplication of efforts.
7. Investigate public and individual complaints regarding improper or illegal hazardous waste activities.
8. Gather evidence, prepare reports and issue notices of violations. Provide technical support to the County District Attorney's Office or State Attorney Generals' Office during prosecution proceedings of violators. This support may include giving depositions or making appearances as witnesses in court.
9. Conduct audits of records of hazardous waste generating industries, including sampling of hazardous waste shipments, to determine, compliance with labeling, packaging and manifest requirements.
10. Develop a notification procedure with each city in the County by which the County Division of Environmental Health will be informed of any new hazardous waste generating industry in the County. This will enable the Division to maintain a current and complete inventory of all hazardous waste generators in the County.
11. Provide consultation and assistance to private and public agencies regarding hazardous materials/waste management, especially the laws and regulations governing hazardous materials/waste.
12. Establish and maintain an information clearing house to provide information on the chemical properties, health effects and safe disposal of hazardous materials/waste.
13. Participate in the cleanup of potential hazardous waste properties in the County. Activities will include identification, characterization, evaluation and approval of cleanup plans and implementation of such plans to completion.
14. Update an inventory of hazardous waste sites in the County; development and maintenance of these sites on County maps

for the purpose of zoning and land-use application.

15. Develop a program for disposal of small quantities of hazardous waste generated by residents of the County.
16. Provide emergency response service in incidents of hazardous waste spills.
17. Privide occupational health and safety services to the generators and operators of hazardous waste facilities for the protections of their employees, in accordance with the requirements of the California Health and Safety Code, California Administrative Code, Title 22 and Title 8.

V. ADMINISTRATIVE POLICY DECISIONS

1. The purpose of a local hazardous materials/waste management program is to significantly reduce the potentials for complaints and incidences of improper or illegal handling of hazardous wastes. The County can accomplish this mainly through the utilization of motivation, training and education. It is the County's responsibility to vigorously enforce all applicable laws and regulations in order to achieve the necessary compliance.
2. To further achieve the goals of this program, a coordination plan should be developed with County Planning, Public Works the Agriculture Departments, the County Office of Emergency Services, the State Department of Health Services, the State Water Quality Control Board, the By Area Air Quality Management District and cities to facilitate information sharing and referral, and to avoid duplication of efforts.
3. It is anticipated that continued industrial growth in local counties will result in ever-increasing amounts of generated hazardous materials/waste which further emphasizes the need to establish and maintain an effective hazardous waste management program.
4. The hazardous materials/waste management program will provide a nucleus and a base line for the "Right-to-Know" element of the County's hazardous materials/waste management program.
5. In order to implement the hazardous materials/waste management program, the County should enter into a Memorandum of Understanding agreement with the State Department of Health Services according to California Health and Safety Code,

Section 25180 and California Administrative Code, Title 22, Section 66360. The agreement shall clearly identify the role and responsibility of both agencies, establish the mode of communication and coordination to assure that the limited resources of the State and the County are utilized in the most effective manner.

VI. ADVANTAGES OF A LOCAL HAZARDOUS WASTE MANAGEMENT PROGRAM

The advantages of a County Program would be that we would avoid:

a. Loss of local control. The State would set all policies, requirements and enforcement procedures. The County would lose any opportunity to control and regulate hazardous materials/waste problems as it deems necessary to provide a high level of enforcement of existing laws with a consequent high level of public protections in this high priority environmental area.

b. A State program may not be responsive to issues of local interest and needs. A County program would allow County staff to address localized problems, safeguard the public health of County residents and respond to public demands for special services based on unique local areas of concern.

c. A unilateral State program generally focuses on the reversal or correction of demonstrated adverse conditions, rather than the prevention of public health hazards, which is one of the primary responsibilities of a County public health agency.

d. A State program does not necessarily provide the level of surveillance and monitoring deemed adequate by local authority to assure compliance by hazardous waste generators in the County.

e. A State program mainly addresses major generators and would not be able to respond as rapidly to complaint requests and emergences as a County program.

Taking the above factors into consideration, a local hazardous materials/waste management program would appear to be most feasible and effective.

Such a program will provide adequate inspections and effective response to complaints and emergency hazardous waste incidents. The County program will be able to vigorously pursue enforcement to compel compliance.

It will also continue the County's participation in the cleanup efforts of potential hazardous waste sites.

As a result, the County will have a more manageable and consistent hazardous materials/waste program with out resorting to the surges of unplanned controls and leniencies occurring after each hazardous waste emergency.

VII. ESTIMATING THE WORKLOAD & PROGRAM COSTS

The annual staff hours needed to operate a comprehensive hazardous materials/waste management program will depend on the number and complexity of the program elements. The total number of staff hours can be extrapolated to staff full time equivalents. Additional costs, such as, fringe benefits, overhead, travel, rtaining, office supplies, field equipment, capital expendature should be considered in computing the overall costs of the local program.

The following table serves as an example of estimating total staff hours needed:

ACTIVITY	FREQUENCY OF INSPECTION AND FOLLOW-UP	HRS/UNIT OF ACTIVITY	ANNUAL STAFF HOURS NEEDED
Hazardous Waste Haulers (XX) Inspections	XX/Hauler/Year	XX	XXX
Hazardous Waste Generators (XXXXX) Inspections	XX/Generator/year	XX	XXX
On-Site Disposers (XX) Inspections	XX/Disposer/year	XX	XXX
Off-Site Disposers (X) Inspections	XX/Disposer/year	XX	XXX
Misc. Hazardous Waste Activities-- Complaints-- Land Use Plans	XX/year	XX	XXX
Emergency Response for Hazardous Material/Waste Incidents (XXX)	X/year	XX	XXX

Training on Hazardous Material/Waste	X Seminars/year X Special training	XX	XXX
Hazardous Waste Legislation Analysis	XX/year	XX	XXX
Potential Hazardous Waste Sites--Cleanup (X)	XX/year	XX	XXX
Occupational Health Inspections (XX)	XX/year	XX	XXX
Staff Traning	XX	XX	XXX
TOTAL STAFF HOURS			XXXXXX

VIII. ESTABLISHING REVENUES TO OFFSET THE COST OF THE PROGRAM

The cost to the County can be totally or partially offset by imposing a fee for Services for establishments handling hazardous materials/wastes in the County. Section 510 of California Health and Safety Code authorizes a local governing body to collect fees for state-mandated activities performed by local Health Officers related to protection of public health. The number of businesses subject to the program services can be identified from the US Department of Commerce Publications "County Business Patterns". The number of establishments in the County, as well as the number of employees associated with Chemical handling industries identified by Standard Industry Classification,"SIC" Codes provided a reasonably good basis for setting a fee schedule.

IX. PROGRAM STAFFING

Due to the comprehensiveness and diversity of a County Hazardous Materials/Waste Management Program, the job specification should reflect extensive demands on the job incumbent in regards to:

1. The knowledge required
2. Supervisory controls
3. Nature of the job guidelines and degree of judgement to apply them
4. The scope and affect fo the work and the product
5. Personnel contacts and the purposes of contacts
6. Physical demands, and
7. Work environment

Comparisons of similar disciplines in local, state and Federal agencies as well as private industry, should be considered in developing the job specifications and compensation. The necessity for the incumbent to understand the complex nature of the industrial operations involved in this program, should be emphasized. In conclusion, the recruitment and retention of highly specialized and trained staff, is the key for a successful local program.

X. PROGRAM ELEMENTS

After evaluting the needs and dimensions of Hazardous Materials/ Waste Management Program in a local County, the County Health

Officer, should select all or part of the following programs elements for implementation.

1. Hazardous Waste Generators Inspections
2. Hazardous Waste Haulers Inspections
3. Underground Tanks Permitting and Inspection
4. Abandoned Hazardous Waste Sites
5. Emergency Response for Hazardous Material Incidents
6. Development of the Hazardous Material/Waste Data Bank
7. Development of the Hazardous Waste Exchange Service
8. Development of Hazardous Material/Waste Disclosure Service
9. Provide Support Services For Land Use Planning and Development Activities
10. Provide Occupational Safety and Health Services To Employees and Employers Involved In Hazardous Materials/ Wastes Activities

THE CHANGING ROLE OF THE FIRE SERVICES IN HAZARDOUS MATERIALS MANAGEMENT

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INTRODUCTION

The fire services in Santa Clara County are being thrust, once again, into a new role. While their responsibilities were for life safety, and were expanded by the hazardous materials storage ordinance to include prevention of environmental pollution, now these responsibilities may increase to include an as-yet undefined role in directing cleanup of leaks detected during enforcement of the preventive codes.

However, groundwater contamination resulting from underground spills is not a problem that confines itself to city or county boundaries. A single regional or subregional agency (such as the Regional Water Quality Control Board, County Health or the Santa Clara Valley Water District) should be responsible for the management and cleanup of our underground resources. At best, this single agency would manage all cleanup cases, from localized fuel leaks to deep groundwater contamination cases. At the very least, this agency would serve as the technical advisor for fuel leaks, having officially delegated limited authority to some local agency for supervision of these incidents, and would retain responsibility for major cleanup cases.

Local fire agencies could provide the follow-up and enforcement in fuel leak cases and perhaps in other leak situations too. But fire does not see itself as the technical expert nor does it have or want the authority to manage the resource.

The fire departments, if they are to continue to provide and even to increase the staff level assistance in leak reporting and investigation that they have been providing for the past several years, must receive technical guidelines and the funding and training resources needed to carry out the program. Transfer agreements are being proposed as a way of achieving these goals.

CHANGING ROLES

The traditional role of the fire services is changing. Where the emphasis used to be "protection of life safety", the role now includes "protection of public health through protection of environmental resources".

This changing role has evolved in response to the recognition that prevention of contamination of underground water resources can be achieved as an extension of the fire code. The change also reflects the belief that local enforcement can be more effective than enforcement by higher levels of government. The distinct lines betwen public safety, public health and environmental health are not so clear as we try to develop a comprehensive approach to hazardous materials management.

Fire Prevention

Fire prevention, through the use of fire and building codes, grew out of the desire to reduce fire loss by reducing the incidence of fires. Cities may use the Uniform Fire Code, the National Fire Protection Association Codes or write their own codes. Construction requirements, sprinklers, and smoke detectors are examples of the type of code provisions that are used to increase the life safety of new buildings. In the semiconductor manufacturing areas typical of Santa Clara County, the chemical hazards are considerably more complex. Many materials are present that cause fires or present a threat to public safety unless properly handled and stored.

The codes have been amended to manage these risks as the fire departments became more aware of the dangers presented. For example, for the safety of their own personnel, the fire departments began asking for information about the types, quantities and location of chemicals. The disclosure process focussed attention on sometimes improper handling, storage and disposal methods. By including hazardous but not flammable chemicals under the purview of prevention activities, the added role of protecting the public (and suppression personnel too of course) from the hazards of these chemicals began.

As the hazards became more obvious and the codes became more complex, Fire Department staffing grew to include hazardous materials response specialists, and in some cities, chemists. Fire prevention inspectors became specialized into such areas as high-rise buildings, educational institutions, and industrial occupancies.

Hazardous Materials Storage

The discovery of groundwater contamination from buried underground tanks led to the development of the hazardous materials storage ordinance (sometimes called the Santa Clara County Model Ordinance). In addition to chemical disclosure and management planning, the ordinance requires leak prevention and detection systems for underground tanks. The storage ordinance requires new installations to provide secondary containment, so that leaks can be observed visually or signalled by some automatic means. Existing installations must install monitoring. Commonly, the monitoring method is one or more wells in the area surrounding the tank(s).

These requirements serve two purposes. First, and foremost in the minds of the fire services, is the detection of leaks before an accumulation of flammable or explosive vapors can occur in underground facilities such as

storm drains, sewers, and utility vaults. Second, detection of leakage at an early stage allows the leak to be stopped and cleanup activity to be conducted before the chemical moves far enough to contaminate the groundwater supply on which so many people in Santa Clara County depend for their drinking water. Thus, the same code that protects the public from fire hazards also serves to protect the public health and the water resources on which the public depends.

The protection provided by the storage ordinance is now recognized as important enough that state laws have been passed requiring similar types of construction and/or monitoring for underground tanks statewide. The laws require regulations to be developed by the State Water Resources Control Board and those regulations to be enforced by local health or fire agencies.

Underground Spill Cleanup

The hazardous materials storage ordinance officially added prevention of leakage from underground tanks to the fire departments' code enforcement responsibilities. During the past two years, however, another big task has come to our attention.

In the process of enforcing the ordinance in Santa Clara County (installing monitoring wells around existing tanks), many apparent leaks have been discovered. We expect to find many more apparent leaks as we proceed with implementation. Estimates of leaking fuel tanks vary from 50 to 80% of all tanks.

The task ahead is to manage cleanup of these leaks before the potable groundwater is affected. When a leak is found, current procedures call for notification of the Regional Board (and other agencies as well). We use a form provided by the Regional Board staff to report what is known and what is being done about the leak.

The State and Regional Boards have the statutory responsibility for directing investigation and cleanup of leaks that pose a threat to the water resources of the state. While the Regional Board has the authority and the expertise to manage spill cleanup, it does not appear to be able to expedite the cleanup of the many small fuel leaks (small compared to the solvent leaks that were discovered by survey in earlier years) that are coming to our attention.

In Santa Clara County, our citizens and elected officials will not let these spills go unmitigated for long. A variety of funding and organizational strategies are being pursued in an effort to improve the level of action toward cleanup in the Santa Clara Valley. One option is local (city) control of certain types of cleanup activity. The investigation and resolution of fuel leaks is often mentioned in this regard. In fact, the Regional Board is circulating proposed guidelines for investigation of fuel leaks for comment presently. The guidelines do not discuss the mechanics of the transfer agreements that would be needed to implement local control.

PROGRAM NEEDS

The fire departments in Santa Clara County, having already expanded their role to include monitoring for and detecting the leaks, fully expect to be the local agencies that county and city officials turn to to take care of this newly recognized work load. Enforcement of cleanup requirements has not come in a timely manner from the state agencies. The fire chiefs realize that they are, once again, regarded as the "logical" locally responsive agency where this additional activity could be handled.

The fire chiefs acknowledge their ability to mobilize for the added work. However, certain needs must be met:

-transfer agreements must be worked out that clearly define areas of responsibility and protocol for leak investigation;

-technical guidelines must be provided for use by their personnel;

-funding for the staff time required and other expenses (eg., laboratory expenses) must be provided; and

-training must be available to ensure a thorough understanding of the applicable state regulations and the proper methods for conducting the investigation and cleanup.

Yet, despite the willingness of the fire services to participate in the leak investigation and cleanup program, the sole responsibility cannot be transfered to the cities because the problem does not confine itself to city boundaries. The resource affected, the groundwater basin, crosses city and county boundaries. A regional or subregional agency should be ultimately responsible for the proper management and protection of the groundwater basin. The Santa Clara Valley Water District and the County Health Department have been suggested as possible alternatives to the Regional Board that is currently responsible for cleanup.

Transfer Agreements

Transfer agreements between state and local agencies have been suggested as a way to allow local management of cleanup programs. State legislative action is required to permit these agreements. There are questions of authority, immunities, and financing which would need to be resolved before entering into such an agreement.

Several bills in the legislature now attempt to deal with these issues. One, AB 853, introduced by Assembly Member Sher, would authorize a city or county to detect and evaluate any hazardous substance released from an underground storage tank, and together with the Regional Board determine and carry out appropriate remedial and removal actions.

The proposed transfer agreements are unique. Although state/local mou's (memoranda of understanding) can be obtained by county health to enforce certain provisions of the Health & Safety Code for the State Department of Health Services, we are talking here about enforcement of Health & Safety and Water Codes by city and county fire agencies.

Guidelines

Technical guidelines are needed before the fire service can assume this new role. Without them, we have been unable to assist the Regional Board with initial investigations because it was not clear what was expected. The methods to be used for investigating leaks must be spelled out. The requirements for lab analysis and evaluation of the results must be set out. The specific levels of cleanup that must be achieved by remedial action need to be known. The acceptable means to achieve those levels must be described.

Fire prevention staff should not be making those kinds of decisions on a city by city basis. Regional or statewide policies are needed. The recently circulated draft fuel leak investigation guidelines may satisfy this need. Protocol for Regional Board/local agency interaction would still need to be defined.

Funding

An obvious need before the fire services can take on added work load is money to pay for the staff time required to follow the leak cases from discovery through remedial action. If confirming lab samples are required, money is needed up front to pay for the analyses even if costs can be recovered eventually. AB 853 would specifically allow local agencies to apply for reimbursement of their costs from the California Superfund.

Training

Any program that proposes to give fire department staff responsibilities in areas outside their fire and hazardous materials code enforcement experience, should provide training in those programs. Topics such as use of the guidelines, analytical procedures, interpretation of results, proper drilling, extraction and treatment methods and equipment and applicable state codes and regulations should be covered. Consultation with Regional Board staff on an as-needed basis should always be available.

CONCLUSIONS

In summary, hazardous materials storage has become a job of immense proportions for the fire services in Santa Clara County. While initially safe storage was the goal, we have found during implementation that many underground fuel storage tanks have apparent leaks. These leaks must be investigated to determine the extent of hazard and contamination. More leaks will be found as we proceed with monitoring and as the rest of the state joins the state-mandated underground tank program.

Cleanup must proceed in order to avoid more expensive efforts in future years. But complex jurisdictional conflicts are hampering our efforts to obtain cleanup of these leaks. Responsible state and regional agencies are not able to handle the job in a timely manner.

Santa Clara County citizens and elected officials are concerned that bureaucratic delays will greatly reduce the effectiveness of cleanup efforts and tremendously increase the cost to the public in the long run by allowing leaks to go unabated long enough to cause further degradation of the groundwater supply.

Transfer agreements are being proposed as a way of achieving this goal. Local agencies could then proceed to manage cleanup of leaks under the general supervision of the responsible state or regional agency.

The fire chiefs will not be surprised if the fire departments are those local agencies. The role of the prevention office has increased in recent years from fire prevention to leak prevention and detection and now to management of underground spill cleanup. The distinction between life safety codes and public health programs has become blurred as the role of the fire services changes. The concept of comprehensive management of hazardous materials takes on new meaning with each new element added to the local programs.

PLANNING A COUNTY-WIDE PROGRAM TO REGULATE UNDERGROUND STORAGE TANKS HOLDING HAZARDOUS MATERIALS

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ABSTRACT

This summary report briefly outlines the process used by the author to plan and develop a county-wide program for the regulation of underground storage tanks holding hazardous materials. The PGOME structure is followed stating the Problem, Goals, Objectives, Methods and Evaluation. The problem was that such a program had to be created in a timely manner. The goal was to do so, and the objectives were to create the elements of the program such as a fee structure, staff training, and the appropriate forms. The methods used were those typical of community organization, i.e., meeting with as many pertinent people as possible, pre-testing forms, sharing information and strengthening contacts which could evolve into an Informational Kinship System. A workshop and a public hearing were held to provide short-term feedback on the program. Almost all objectives and goals were realized in the allotted time, and program feedback was enthusiastically positive.

I. WHY REGULATE UNDERGROUND STORAGE TANKS?

Telephone conversations with the State Water Resources Control Board reveal that at least one hundred and seventy five thousand underground structures (tanks, sumps, etc.) holding hazardous materials have been registered in the State of California under the requirements of the Cortese Bill. This is not an all-inclusive count.

Nationally, the sheer volume of underground storage tanks holding hazardous materials and the age of the majority of the tanks combine to create a serious threat to groundwater resources.

The insidiousness of leaking underground storage tanks is that they tend to leak slowly, too slowly to be found through gauging or inventory reconciliation alone. And yet, a very small leak, as little as a loss of one gallon of gasoline per day, for example, can pollute the water supply of a 50,000 person community to a level of 100 parts per billion.[1]

Approximately 23-37% of the water used in this country is derived from groundwater sources.[1] For rural households, approximately 90% of all drinking water comes from groundwater sources.[1]

Combining this information with survey findings suggesting that 30% of all existing tanks may be leaking, and an awareness of the difficulty and expense involved in attempting to recover groundwater resources which have become contaminated with hazardous materials, the magnitude of the potential environmental threat posed by leaking underground storage tanks becomes clearer.

The intent of underground storage tank regulation is to protect public health and safety, minimize damage to the environment and wildlife, and to protect property from the adverse effects of hazardous materials.

II. BACKGROUND

The author was hired by a Southern California County to plan and create a program to implement an ordinance regulating the storage of hazardous materials in underground storage tanks. The summary report which follows briefly describes the process used in the planning and creation of that program.

The planning structure used here is the "PGOME" method - Problem, Goal, Objectives, Methods and Evaluation.

III. PROBLEM STATEMENT

The problem expressed by the County was that an ordinance had been adopted for the regulation of underground storage tanks holding hazardous materials but no program had been planned or developed to implement this ordinance.

The primary problem then, was that a comprehensive county-wide program needed to be planned and created in a timely manner which would provide regulatory mechanisms for accomplishing the intent of the ordinance and would do so with integrity and flexibility.

Secondary problems immediately became evident. For example, the author had a great deal of community program development experience, but no knowledge specific to underground storage tanks; and, an information sharing system needed to be cultivated to protect the future integrity of the newly planned program.

IV. GOAL STATEMENT

The primary long term goal became to plan and create a program which would regulate the underground storage of hazardous materials in tanks. This program would be one which would meet the intent of the pre-existing ordinance and would demonstrate both integrity and flexibility in its administration.

A secondary long term goal was the development of an information sharing system and knowledge base upon which the program's

relevance and integrity could be maintained on a long term basis.

An additional secondary goal was the education of the program planner to a level of technical fluency and community awareness which would enable the formation of an appropriate program.

V. OBJECTIVES

In planning a program such as this one, it is important that specific written timelines be assigned to each objective. The timelines and/or the objectives may need revision at a later date but it is crucial to have a focused direction in which to work on a daily basis.

The author recommends placing problem statements, goal statements, and objectives in a prominent spot in the work area so that they can be seen and reveiwed daily.

In this instance, many objectives were generated with very short timelines due to the need to get a program developed as rapidly as possible.

The following is a partial listing of the objectives used by the author:

1. creation of a fee schedule and a program budget for a self-funding program;

2. development of a staff training report detailing the training needed by staff to work in the established program, and potential resources in the community for meeting those training needs;

3. drafting a Memorandum of Understanding to be signed by the Fire Departments, Building Department, Air Pollution Control District, and Environmental Health, detailing each agency's inspection responsibilities, etc., to preclude any duplication of County services;

4. drafting of all necessary permit applications, inspection forms, routing forms, etc.

5. writing the technical guidelines delineating how the ordinance would be enforced with regards to equipment standards, field inspections, plan checks, etc.

6. holding a public hearing to discuss the guidelines described above; and

7. perform all field inspections, clean-up inspections, etc. germane to the program.

As the last item reveals, the planner was doing the field work of the program in a limited way while also designing and developing the program. The decision was made to do both simultaneously to provide

reality-testing for the program in each stage of its growth.

VI. METHODS

The basic methods used in any community health program development were used here. Two of these cannot be emphasized enough:

1. talking to people, and

2. listening to people.

The author met with contractors, manufacturers, consultants, county agencies, testing and standards organizations, professional associations, community members, petroleum industry representatives, etc.

As many questions as could be generated were asked and repeat visits with individuals were made if needed.

For example, meetings were held with a representative from Underwriters Laboratories to discuss their testing and listing standards for underground storage tanks for hazardous materials, to explore their listings on corrosion protection of tanks, to determine the extent of their involvement in the industry, the history of that involvement, and so forth.

Meetings were held with members of professional associations such as the National Association of Corrosion Engineers, to discuss holiday testing methods, ranges of soil conductivity, sacrificial anode systems, etc.

Meetings were held with manufacturers to discuss quality control in their industries, testing standards, seismic stability of products, warranties, installation instructions, contractor certifications in installations, and so forth.

Many meetings were held with government agencies to discuss regulation of their own tanks, concerns specific to their departments, the permitting process, etc.

The above is just a glimpse of the type of questioning, information gathering, and resource exploration that was done during the planning and creating stages of this program's development.

Meeting with people is critical, and may even be the heart of a program's eventual success. The meetings are important not just for the opportunity they afford to generate and absorb valuable information but also because they demonstrate a willingness to work with people in a cooperative manner. If this willingness is genuinely expressed, any threatening aspects of the program can often be minimized and successes maximized.

Also, a lot of telephone research was done which both gathered the information needed to meet specific objectives and formed the foundations for the Informational Kinship System seen as

a goal from the beginning.

Forms and guidelines were pre-tested and circulated among representative populations for critical feedback as they were created.

Any pertinent reading material that could be located was read, including manufacturers' information, testing standards, technical bulletins, etc. There was at this time no budget alloted for resource materials so these had to be obtained as possible on a no-cost basis.

Also, an extensive review was made of all forms, policies, fee schedules, etc. developed by other counties in an effort to prevent re-inventing the wheel wherever it was appropriate to do so.

An effort was made throughout to keep Higher-Ups informed of progress, set-backs, needs, timeline revisions, and successes. It is as important to share information internally as it is to do so with the impacted community during program planning and development. Without such sharing, a supportive base for the program cannot be sustained.

In-house briefing of the Environmental Health staff was also provided to enhance their awareness of the newly forming program and to assure their feeling of being included in its evolution. Guidelines, forms, etc. were routed to the general staff for their reveiw.

A running "issues list" was kept of any questions for which good answers simply did not exist and these were discussed at the management level as needed.

Field inspections of newly constructed, leaking, and abandoned underground storage tanks for hazardous materials were performed by the author throughout the planning and development stages. The "hands-on" experience gleaned in this way was crucial to the program's later success.

VII. EVALUATION

A long term evaluation was not possible due to the time limitations involved, so two events were organized by the author to help generate some short term evaluation data.

The first was a public hearing to discuss the guidelines which detailed the ways in which the program would be administered. The guidelines specified product requirements, testing requirements, permit requirements, fee requirements, inspection requirements, etc. In a sense, the guidelines defined the planned body of the underground storage tank program.

The second event was a workshop open to representatives of agencies

regulating tanks throughout the State of California. This was a technical workshop designed to enlarge the volume of shared knowledge in this area; to facilitate information, resource, and skills exchanges between professionals; and to generate pertinent feedback on the developing program.

Both events were tremendously successful and provided both helpful suggestions and a great deal of affirmation for the program.

It is the author's belief that evaluations are an essential aspect of any public health program and need to be included as an on-going process.

VIII. SUMMARY

A program to implement an ordinance regulating the underground storage of hazardous materials in tanks was planned, developed, and implemented using the PGOME system.

Problems, goals, and objectives were clearly defined and accomplished via classic community organization methods such as informational sharing meetings, phone calls, and document review.

The objectives and goals of the program were realized within the allowed time for their accomplishment. A possible exception to this statement is the Memorandum of Understanding which remained unfinalized at last report.

[1] "Underground Tanks Contaminate", EPA Journal, Vol. 10, No. 1, January - February 1984.

HAZARDOUS WASTE FACILITY SITING

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INTRODUCTION

Hazardous waste management has been called the leading environmental problem and challenge of the 1980s. However, the most difficult task has become that of siting the needed facilities to treat, transfer, store and dispose of the hazardous wastes about which the public is so concerned. The March, 1985 issue of National Geographic summarized the problem thusly:

> "Fearing the worst, we've grown as grim about hazardous wastes as people menanced by plague, and in the bitterest irony of all, modern waste management plants that could spare us future harm and worry are no more welcome in our communities than dumps. NIMBY - 'Not In My Back-Yard' has become our watchword."

In this paper, I have chosen to discuss the siting of hazardous waste facilities using the analogy of a recipe - a complex mixture of ingredients that must be blended in the proper proportions, at the right times, and cooked at the correct temperature for a precise amount of time, or the ultimate product will be a failure. What makes hazardous waste facility siting so difficult to do is the lack of a cookbook - we are using trial and error methods, and searching for the right recipe.

Through many unsuccessful siting attempts and a few that worked, we have found that there are five major ingredients for a successful hazardous waste management facility. These are technical, political, business, social, and governmental (or regulatory) ingredients. Each of these will be discussed below.

Note: The views expressed in this paper are those of the author and not necessarily those of the Los Angeles County Sanitation District.

TECHNICAL INGREDIENTS

The technical ingredients of a hazardous waste management facility are probably the most important. In my opinion, if you don't have these, you may as well abandon the effort. These "ingredients" can be classified as shown below.

Need

There must be a demonstrable need for a proposed facility. The public will react very strongly against a facility which does not appear to solve a problem. The prospective operator must be prepared to demonstrate why this particular project is necessary to local industry and the general public well-being.

Location

A hazardous waste management facility should be in a location that is compatible with the operations planned there. The zoning and previous use of the land are good benchmarks by which to measure this. Adjoining uses must also be considered. As an extreme example, the land immediately adjacent to an elementary school ought to be eliminated early in the site search. Isolation from homes and immobile populations (hospitals, prisons, etc.) is beneficial. Other common-sense items include siting facilities where access is good, at a location that has adequate sewer capacity (for treatment and volume-reduction facilities), and avoiding seismically unstable and flood-prone lands. The last consideration for the location is that it should have been selected in a reasoned way - not simply because it was owned by the project proponents.

Operator

The operator proposing to run the facility should be free of major problems in the hazardous waste management field. It is beneficial if the operator has a good reputation, with a history of doing things right. It is also important that the prospective operator have the resources to do things right, and effectuate cleanup in the event of problems.

Technical Proposal

The project should be well thought out, with all aspects of waste management clearly explained. Contingencies should be frankly discussed, and not glossed over. Permitting agencies should not have to come back to a proponent several times to get good answers to questions about how they propose to manage wastes at a facility.

Risk Management

Hazardous waste management facilities can operate with risks no greater than the industrial facilities they serve. In most cases, the risks will actually be less than for other industries, because the chemicals handled are not full strength raw materials, but spent chemicals whose hazards are diminished. The hazards posed by a waste treatment facility will depend on the following factors:

- the types and amounts of wastes handled
- the inventory of wastes onsite
- the treatment processes used
- the byproducts and effluents produced

A facility's proponents should be able to demonstrate that its existence will lessen the overall risks faced by the surrounding communities, due to technically better waste management activities, lessened long-haul transportation, and the decreased risk of illegal dumping.

POLITICAL INGREDIENTS

Since waste management facilities must ultimately secure approval from elected officials, it is important that this ingredient be involved in the recipe from its early stages. One of man's shortcomings, as a species, is his inability to predict the future. Consequently, we react well to hazards known from the past, but not nearly so well to those hazards that we don't know about for some time.

Elected officials are human too (despite what you may see on the evening news). They react well to the problems they know about, but do not pro-act well to unknown dangers. They need to be informed by the facility proponents about the dangers that a hazardous waste management facility will prevent. They should be completely informed early in the planning stages of a project. "No Surprises" is a good dictum to follow in dealing with them.

It may be advantageous to site facilities in unincorporated county land rather than in incorporated cities. County elected officials often have a broader perspective on issues that city elected officials do not share, due to the limited perspectives and interests of their constituents.

Obtaining the support of community and business leaders can be useful in siting efforts. It is also critical that the proponents quickly learn all the agencies that have regulatory authority over the project. Nothing is more damaging to a proposed facility than to be in a public meeting and to be caught unaware of some regulatory hurdle that a facility will have to clear.

BUSINESS INGREDEIENTS

Probably the single most valuable ingredient a business enterprise could have when entering the hazardous waste management business is patience. It takes many years to get permits granted, facilities sited and constructed, and revenues flowing from the operations. Certain industries, such as commercial aircraft manufacturing, must make large capital expenditures years in advance of their first sale. Hazardous waste management will be similar in its expenditure and revenue cycles. On the other hand, if an industry is used to receiving revenue within a month or two of investing capital, it will not have the temperament to prosper in the hazardous waste management business.

Other valuable business ingredients in this recipe are stability and a significant amount of financial resources. Citizens and elected officials will be wary about granting operating permits to a company that does not have some history of doing things right, and that cannot commit substantial resources to problem solving if things go wrong. The history of hazardous waste management is replete with problems caused by under-capitalized buinesses. This is one segment of the economy that "Mom and Pop" companies should avoid.

One last business ingredient that is needed is a visible endpoint to the permit process. This must be supplied by the regulatory and land use permitting agencies. Business is willing to invest in a high-risk endeavor such as hazardous waste management, but only if the potential rewards are correspondingly high. The present system of virtually open-ended permitting makes hazardous waste management a poor business proposition. Until this ingredient is added, it will be difficult to attract major new investments into hazardous waste management projects.

SOCIAL INGREDIENTS

These ingredients are probably the least well defined, but may be the most important in getting through the permit process. The facility should fit into an equitable system for distribution of risks of hazardous waste management. This usually entails a balance between treatment facilities in industrial centers, and residual repositories in remote areas. All of us enjoy the fruits of our industralized society, and consequently, all of us should share in its risks as well.

Trust and openness are two key ingredients in convincing people that a facility can work. Deception has inevitably returned to haunt those who hid the facts in the hazardous waste management business. An unwillingness to face the public and answer questions will also engender fear and mistrust by local citizens. Once a facility is sited, these lessons must not be undone. Allowing people to come

onsite and look around will ease many of their fears. Violating previously agreed-upon permit conditions for short term profits because it is legal to do so will undo in days the trust it took years to build.

One additional social ingredient that can be very useful is media interaction. Going to the media before they get to you can be useful. If you feel that a story is untrue or slanted, a professional reply should be sent to the paper or station. In dealing with the media, an old football axiom applies: "The best defense is a good offense."

GOVERNMENTAL INGREDIENTS

Citizens do not trust operators of hazardous waste management facilities. They rely on regulatory agencies to keep an eye on the operators, check their process results, and monitor the ground water near their sites. It is crucial that citizens have regulators they can trust. Therefore, the next ingredient needed for hazardous waste facilities is a competent, well-staffed regulatory agency. The regulators must also be pragmatic, able to separate inconsequential, technical violations from those that endanger public health and safety. When the latter are found, they should be virgorously prosecuted. Nothing destroys the credibility of a regulatory agency as much as a seeming inability to enforce their standards.

SUMMARY

Many ingredients go into a well-made meal. Similarly, there are many components to successfully siting hazardous waste management facilities. No completely successful recipe has been found for this. Many "cooks" are blending the ingredients by trial and error, hoping to find a combination that works. All of the above ingredients must be included - however, the timing and proportions are subject to experimentation and debate. These are summarized below:

Technical - we need the right facilities in the right places. Without this ingredient, we may as well abandon the project.

Political - the elected decision-makers must allow good facilities to be situated in proper locations.

Business - economically unviable facilities will soon sink of their own weight, either in the permit process, or worse, after construction.

Social - the people near a facility must accept it if it is to work. Legal (and illegal) methods will be used if citizens are convinced that they are not being treated fairly.

Governmental - The permit process must deliver timely, workable decisions, and enforce upon both faciltiies and illegal disposers. Unless the public has reason to trust the regulators, they will never believe that a hazardous waste management facility can be run correctly.

In summary, it takes good ingredients to make a good meal. Any one ingredient can ruin the dish, if it is out of proportion, spoiled or added at the wrong time. We cannot say what the precise blend of ingredients should be for any given facility - we are learning by trial and error. However, if you try to site a hazardous waste management facility without using all of these ingredients, we can almost certainly guarantee failure.

REFERENCES

A more complete discussion of various industries' attitudes and capabilities for long-term, capital-intensive risks can be found in "Corporate Cultures - The Rites and Rituals of Corporate Life" by Terrence Deal and Allan Kennedy, Addition Wesley Publishing Company, 1982.

ACKNOWLEDGEMENTS

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TREATMENT, STORAGE, AND DISPOSAL FACILITY AUDITS A WAY TO REDUCE CORPORATE LIABILITY

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In today's business climate, a key concern of hazardous waste generators is the reduction of corporate liability. One way to reduce potential corporate liability is through proper disposal of hazardous waste. But, how does a generator know that its hazardous wastes are being disposed of in accordance with appropriate regulations and at facilities that provide maximum security? Auditing treatment, storage, and disposal (TSD) facilities is a good way to answer this question. With the Resource Conservation and Recovery Act's premise that a generator is responsible for its hazardous waste from cradle to grave, knowing the condition of that grave becomes extremely important. The Stringfellow Acid Pits in California, the Lowry Landfill in Colorado, and the Seymor Disposal Facility in Indiana are just a few examples of hazardous waste disposal facilities that have become major Superfund sites with staggering cleanup costs. Prevention of becoming financially responsible for a portion of site cleanup costs is another incentive for conducting TSD audits.

The question of who should perform the facility audits needs to be answered at the outset. One option is to conduct the audits with in-house corporate or facility environmental staff. Another option is to retain a qualified consultant to perform the audits. The primary considerations in determining which option to select include cost, available staff resources, and technical expertise. Costs for performing site audits can be obtained from consultants and compared to the costs of utilizing in-house staff. Availability of in-house staff to perform the audits, which is largely dependent upon the number of staff available and the number of facilities to be audited, must be assessed. It also is necessary to assess the consultant's ability to perform the number of audits required within the time frame desired. It must be determined if in-house staff has the required technical expertise to adequately evaluate the regulatory, environmental, and engineering factors associated with TSD facilities. There also is an experience factor that must be considered for both in-house staff and consultants.

The next question to be asked is what should the audit consist of? There are many ways to perform TSD audits; the methodology described below has been used successfully over two hundred times. From an overall perspective, the generator needs to determine the number and priority of TSD facilities that need to be audited, perform the audit, determine the liability that a TSD facility may represent to the corporation, and determine the advisability of continued use of the facility. These major components are discussed further below.

SELECT AND PRIORITIZE FACILITIES

Normally a generator conducts a survey of their corporate facilities to determine the number and location of TSD facilities that are being used. Each corporate facility also needs to determine the type of hazardous waste generated and its volume. Once this information has been compiled, the TSD facilities to be audited can be selected and prioritized. It is helpful to have some information on the TSD facilities so that an initial assessment can be made to determine which sites might pose the greatest risk.

If not already developed, a site evaluation form should be prepared at this stage. The components of a typical form are discussed later in this paper.

AUDIT COMPONENTS

Once the TSD facilities have been selected for audit and prioritized, it is time to conduct the audits. The primary components of the audit include scheduling, conducting the audits, interviewing the regulatory agencies, and preparing an audit report.

Schedule Site Audits

The first task is to develop a program schedule for the number of TSD facilities to be audited. The schedule can be short or long depending upon the number of facilities, the staff resources available, and the urgency to complete the audits. Once the program schedule is developed, then the individual facility visits can be arranged. It is important that a letter of introduction be sent to the facility about a month before the visit. The letter of introduction should be short and should inform the facility management of your intent to conduct an audit, introduce the person who will conduct the audit, and present a request for the data to be available when the auditor arrives at the facility. The data request should include hydrogeologic reports, monitoring results, permits, insurance and financial reports, and documents pertaining to compliance issues.

Following the issuance of the letter of introduction, the facility management should be contacted and an actual date set up to conduct the site visit. An appointment also should be scheduled with one or

two of the primary regulatory agencies. If there is more than one TSD facility that is regulated by the same agency, it may be cost-effective to schedule multiple facility audits such that the regulatory agency only has to be visited once.

Conduct Facility Audits

Conducting the facility audit consists of three main components. These include an interview with the facility management, completion of a site evaluation form during the interview, and an inspection of the facility.

Topics to be discussed during the interview with the facility management include the facility's organization, the parent company or corporate organization, the site history, and past, present, or anticipated regulatory problems. During this discussion, the site evaluation form is filled out. This form is a "fill in the blanks" questionnaire that covers all applicable areas of concern regarding the facility. The form generally consists of the following items:

General Facility Information - This section covers areas of the facility location, address, regulatory knowledge, adjacent receptors, characteristics of adjacent neighborhoods, and other TSD facilities that the company may own and/or operate.

Facility Capabilities - This section addresses the facility's treatment, storage, and disposal capabilities, their construction features, waste types that are accepted and excluded at the facility, and control measures for surface water and leachate. It also addresses the record keeping procedures for waste analyses, training, manifests, etc.

Operational Quality Control - The focus here is on the waste acceptance procedures the facility uses, types of waste analyses performed at the site, tracking systems, and controls for the waste streams, and on-site or off-site laboratory capabilities.

Geology/Hydrology - Generalized information should be obtained on the site geology and soil characteristics, the presence and condition of surface and/or ground water, facility monitoring programs, and current results of the monitoring program.

Facility Appearance - Data on the on- and off-site appearance of the facility, the presence, type, and condition of safety equipment, and the emergency response capabilities (medical and fire) are compiled in this section.

Permits - This section addresses the local and state permitting agencies and the types of facility permits in effect. This section also addresses the status of the facility's Part B permit application and the key features of the application.

Insurance/Financial Integrity - Information gathered here concerns the general insurance coverage that the facility and/or corporate entity have, the type and limits of environmental impairment liability insurance, the financial status of the company including available financial reports, and compliance with the closure and post-closure financial requirements.

After completion of the management interview and the site evaluation form, an inspection of the entire facility should be conducted. In is preferable to do this on foot rather than in a vehicle so that the various features can be inspected in detail. For large sites, this might be impractical; however, each prime feature should receive close inspection. The inspection usually begins in the office by reviewing record keeping procedures and the laboratory facilities. Next, close inspection of the various treatment, storage, and disposal units should be conducted. Questions should be asked as to their construction, types of wastes that are handled, how the wastes are handled, and the actual performance of the unit relative to its intended performance. Construction and safety equipment should be reviewed as well as the location and types of monitoring systems at the facility. Overall impressions of interior and exterior housekeeping should be noted.

Upon completion of the site inspections, the impressions gained during the facility audit should be recorded as soon as possible. Using a portable tape recorder is an effective tool to retain bits of information gathered during the audit.

Interview Regulatory Agencies

The next step is to visit the two primary regulatory agencies. This may include a local and a state agency, a state and a federal agency, or even multiple state or multiple federal agencies. It is advantageous to interview the primary person responsible for inspecting the facility as well as his supervisor who is normally more aware of the political and environmental issues and the regulatory policy affecting the facility. The interview should focus on the site's history, its compliance with the various regulations, and enforcement actions that have taken place, are in effect, or are anticipated. It also is advisable to obtain the regulatory agency's opinion on the operations of the site, the attitude of the facility management, and their perception of the public's opinion of the facility. Upon completion of the interview, the regulatory agency files should be reviewed for information and issues that may not have surfaced. Copies of appropriate documents should be obtained including:

permits, enforcement actions, complaints, correspondence with the facility, and appropriate technical reports. It may be necessary to ask additional questions of the persons interviewed to clarify issues uncovered during the file review.

Prepare Audit Report

It is advisable to put all of the information collected in a written report that can be a permanent record and be submitted to other corporate personnel for review. The format and type of information presented in the report depends upon many factors. The following discussion presents a format that has been used successfully in the past.

A short summary should be prepared of the findings of the audit, the concerns identified, and recommendations for follow-up actions. The summary is often useful for forwarding to the particular corporate facility that is using the TSD facility so they have a record of the essence of the audit.

The main components of the report may consist of the following sections:

1. Facility description

    a. Type of facility
    b. Location/size
    c. Personnel and security
    d. Geology/hydrology
    e. Authorized and excluded wastes
    f. Disposal/treatment methods
    g. Monitoring/laboratory facilities
    h. Regulatory compliance
    i. Regulatory/public opinion
    j. Potential for release to the air, surface, and ground water

2. Site Evaluation Form

3. Additional Site Information

4. Permits

5. Regulatory Agency Interviews

6. Appendixes

    a. Facility plans
    b. Hydrologic reports
    c. Operations reports
    d. Monitoring reports

e. Regulatory agency correspondence
f. Facility brochures
g. Financial reports
h. Others

MAKE THE DECISION

The facility audit report should be reviewed by the appropriate corporate personnel. These people need to assess the liability that a particular facility poses to the corporation. There are many factors that should be considered in making this determination. For instance, the technical strength (integrity) of the facility is very important. The stronger the facility is technically, the less chance for contaminant releases and, therefore, it poses a lower level of potential liability. The financial strength of the facility and the parent company or corporation also is important. In essence, the larger the corporation, the lower the chances are that they will seek remuneration from the generators. The placement of restrictions on a facility or restricting wastes disposed of at the facility can be effective ways to reduce potential liability. It is important to look at the availability of alternative facilities that may be able to provide equivalent services with a lower potential liability for the generator. Of course, the costs of options other than continued use must be weighed against the potential liability for a given facility.

Using data from the facility audit and the liability assessment factors, a decision must be made to continue to use the facility, discontinue its use, impose restrictions on the facility or select an alternative facility.

In summary, the auditing of hazardous waste treatment, storage, and disposal facilities should be a key element of a corporation's program to minimize liabilities associated with disposal of their hazardous wastes. The days of "out of sight, out of mind" are long gone and have been replaced by definite concerns for the proper disposal of hazardous wastes in a manner such that corporate liability is minimized.

INSURING THE HAZARDOUS WASTE RISK

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INTRODUCTION

The problem begins with an accidental spill requiring expensive cleanup and subjecting the polluter to third party liability. The dimensions of insuring a pollution claim can be truly staggering. The insurance industry often points to the need for predictability and certainly in evaluating a risk. However, the potential damages from hazardous substances may range from small health claims to the cost of relocating an entire community. This obviously lends a great sense of unpredicability to the liability market.

Today, environmental contamination incidents, identified by various Federal and State agencies, consistently appear as news on a National level. The public is rightly concerned over the proper disposal of hazardous substances. The regulatory community has reacted to the public concern by enacting legislation focusing on the requirement that persons and companies dealing in hazardous materials demonstrate some type of financial capacity to pay for harms. Accordingly, legislators have looked to the insurance industry as a source of funds for pollution clean up, defense and indemnification.

The insurance industry has responded to the "financial responsibility" requirements promulgated by our legislators. However, such catastrophic and well-publicized events such as Love Canal and Times Beach, have cast a reluctance among insurance companies to underwrite a hazardous waste risk. In addition, most courts have broadly construed the pollution exclusion found in most standard Comprehensive General Liability (CGL) Policies. This judicial interpretation has often afforded pollution coverage to the insured, resulting in unanticipated indemnification and defense costs from the standpoint of the insurance carrier.

When these facts are combined with the reinsurance crunch and the hardening marketplace, the result for the hazardous waste risk is reduced capacity, selective underwriting and a dramatic increase in premium.

This paper will explore the following areas affecting the Hazardous Waste Industry:

I. Financial Responisbility Requirements
II. The Distinction Between "Sudden and Accidental" v "Gradual" Coverage
III. The Changing Marketplace
IV. Future Expectations

I. FINANCIAL RESPONSIBILITY REQUIREMENTS

The Resource Conservation and Recovery Act (RCRA) enacted by Congress on October 21, 1976, was the first Federal legislation addressing the problems of Hazardous Waste and Financial Responsibility. The goal of the RCRA Hazardous Waste Program is to regulate all aspects of the managment of a hazardous waste from the time of generation to the time of proper disposal. Under RCRA, the Environmental Protection Agency (EPA) required certain levels of liability protection for both sudden and non-sudden incidents.

In the final promulgation of Financial Responsibility regulations effective July 15, 1982, treatment, storage and disposal facilities (TSD's) were obligated to provide a limit of bodily injury and property damage liability for sudden and accidental incidents of $1 million for any one occurrence; $2 million annual aggregate. Effective January 1985, all surface impoundments or landfills involved in the treatment, storage and dispsal of hazardous wastes are required to provide non-sudden liability coverage of at least $3 million per accident; $6 million annual aggregate.

The EPA has allowed a staging of this non-sudden requirement as follows:

January 1983: Firms with annual sales of $10 million or more
January 1984: Firms with between $5-$10 million annual sales
January 1985: All others

It is important to note that the limits of liability must be exclusive of defense costs. In other words, limits of liability cannot be reduced by the claim costs of the insurance carrier. If the policy provides for defense costs as part of the limit of liability, it is imperative that higher limits be obtained in order to comply with the regulations.

RCRA also mandates the addition of the Hazardous Waste Facility Liability Endorsement to all TSD policies. This endorsement re-defines some of the terms and conditions of the standard liability insurance contract. A serious problem develops with this endorsement as it amends the policy to "provide insurance in accordance with the provisions of such regulations to the extend of coverage and limits of liability required."

The effect of this language is that the policy of insurance for

TSD's must follow the regulations in every aspect. Since the regulations are largely unenlightening with respect to congressional intent and subject to constant judicial intepretation, a carrier never really knows what coverage is provided to the insured. Many companies have consequently been reluctant to provide this endorsement.

In reviewing the language of this endorsement it becomes clear that the insurance carrier continues to have a right to effect any conditions or exclusions contained in the policy as long as the ramifications of this action only affect the insured. In orther words, if the insurance carrier is required to pay a claim (that the carrier would not otherwise) have been required to pay), becuase of the language contained in this endorsement, the company retains the right to request payment from the insured. It is important that the insured understands the potential ramifications of this endorsement.

RCRA also mandates that guarantees be provided for Closure/Post Closure costs for most TSD's. These guarantees can be provided in the form of:

1. Insurance
2. Financial guarantee (e.g., Irrevocable Letter of Credit)
3. Surety Bonds
4. Collateral Bonds
5. Trust Funds and
6. Self insurance

Only one carrier has offered an insurance contract for Closure/Post Closure costs to date. However, it has been announced most recently that the carrier was withdrawing from the marketplace.

Surety companies have hesitated to provide bonds due to the long-term nature of the permits. As Surety Bonds are not easily cancelled, most Surety companies feel it is very difficult to determine a company's financial conditions as long as 30 years from the date the bond is provided. Where Surety Bonds have been provided, either a large company has been involved or complete non-cancellable collaterial has been required of the TSD. The most popular method for handling the Closure/Post Closure requirement has been the Fiduciary Trust. Under this agreement, a Trust is established, perhaps at a bank, which funds the estimated Closure cost of a facility by annual deposits over a period of years. This method spreads the cash impact over a longer period of time. In order to provide self-insurance, a company must pass a series of stringent financial tests. It is apparent that only very large companies will qualify for self-insruance. The issues of Closure/Post Closure costs generates obvious concern among TSD's. The need to guarantee Closure/Post Closure costs of a facility is warranted. However, the insurance and surety industry's problems with providing what basically amount to a guaranteed annuity, is also understandable. Alternative methods of financial must be made available to address the problem.

The Motor Carrier Act of 1980 (MCA) established minimum standards of financial responsibility for those companies involved in the transportation of hazardous materials. Effective January 1, 1985, most transporters are required to carry $5 million of coverage.

In addition to the mandated minimum financial responsibility limits, the MCA also requires a policy endorsement titled MCS-90. This endorsement modifies the policy language in the same manner as the Hazardous Waste Facility Liability Endorsement. The effect of the endorsement is to guarantee that the insurer will satisfy third-party liability claims. The endorsement itself does not change the insured's coverage. However, in accordance with the endorsement language, the insured would be required to reimburse the insurer for any payments that, in the absence of the endorsement, the insurer would not have been obligated to incur. Essentially, the insurer maintains the right to subrogate against the insured for losses paid which are directly attributed to the endorsement.

The Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA), commonly known as "Superfund", was passed by Congress and signed into law on December 11, 1980. CERCLA was designed to address the needs for a comprehensive system to respond to releases of hazardous substances into the environment and impose liability on those parties responsible for such releases.

It is important to recognize the relationship between RCRA and Superfund. RCRA provides a regulatory program for active facilities that handle hazardous waste. Thus, it is basically prospective in nature and does not address problems of contamination from abandoned facilities or releases of hazardous substances from vessels or facilities which are not subject to RCRA. Superfund provides a response program to deal with releases of hazardous substances from any type of facility, at any time.

Similar to RCRA, Superfund is administered primarily by the EPA. Unlike RCRA, however, Superfund does notinvolve extensive regulations. Rather, Superfund imposes reporting and clean up requirements on those owners and operators of vessels and facilities from which occurred a release of hazardous substances or "pollutants and contaminants". If a responsible party fails to report and clean up the release, the Federal government may undertake the clean up and recover the costs of clean up from the responsible party.

Those who are liable for costs of clean up include any present or former owner or operator of a site where hazardous substances have been disposed, any transporter who selected the site for the disposal, and any generator who sent the waste to the site for disposal. Consequently, there may be hundreds of potentially responsible parties who have disposed of their waste at a site over a period of many years. The case law begin developed and litigated under Superfund has been most favorable to the government. Courts have consistently allowed the application of not only strict liability but joint and

several liability upon responsible parties for the costs of clean up and remedial action. Basically, Superfund has established its own liability system. The law strips the responsible party of many common law defenses against liability and eliminates many of the policy defenses that may be available to an insurance company in the normal insurer-insured relationship.

II. THE DISTINCTION BETWEEN "SUDDEN AND ACCIDENTAL" v "GRADUAL COVERAGES

The most basic business insurance coverage is obtained by writing a Comprehensive General Liability (CGL) Policy. Since 1973, the most standard CGL Policy has incouded language commonly referred to as "the Pollution Exclusion". This exclusion removes from coverage, damage for the discharge, dispersal, release or escape of pollutants; but the exclusion does not apply "....if such discharge, dispersal, release or escape is sudden and accidental."

The insurance industry has traditionally defined the terms sudden and accidental as: definitive in time and place and a fortuitous event. Consequently, Environmental Impairment Liability Insurance (EIL) was conceived to fill the gap in the standard CGL Policy, which covers claims from a pollution incident only if the occurrence is sudden and accidental. EIL, on the other hand was created to protect companies from liability resulting from a gradual type pollution.

However, the majority of most recent cases tend to interpret the pollution exclusion to require the insurer to defend and/or indemnify the insured even though the damage appears to stem from a gradual type pollution.

The lead case interpreting the standard pollution exclusion is Jackson Township Municipal Utilities Authority v Hartford Accident and Indemnity Co. 186 NJ Super 156,451 A2d 990 (1982) ("Jackson Township"). The issue in Jackson Township was whether the general liability insurance carrier owed its insured a duty to defend and indemnify when it was charged with negligently polluting groundwater, causing property damage and personal injury. In the Jackson case, liquid waste from the township landfill leaked through the soil polluting the aquifer and contaminating nearby drinking wells. The township was sued by residents for intentional wrongdoing, nuisance, trespass and negligence.

Jackson Township brought a declaratory judgment action against its insurance carriers for a determination of liability under the general liability policies for damages and clean-up costs. The policies insured against claims for bodily injury or property damage caused by an occurrence which was defined as meaning an accident "neither expected nor intended from the standpoint of the insured." The insurance company argued the pollution exclusion clause as stated above, precluded liability. The Jackson Township court held that the exclusionary clause was simply a restatement of the definition of

occurrence. The policy, therefore, covered pollution claims where the injury was "neither expected nor intended". The standard pollution exclusion clause did not preclude indemnification for accidental pollution. The Court ruled:

> The chemical manufacturer or industrial enterprise who discharges, disperses or deposits hazardous waste material knowlingly, or may have been expected to know that it would pollute, would be excluded from coverage by the clause.

The Jackson Township case suggests that coverage under the CGL Policy will not be provided for the "intended results of intentional acts", despite the gradual type nature of the pollution.

A case by the Washington Court of Appeals also addressed the issue of coverage for gasoline leaks. United Pacific Insurance Co. v Van's Westlake Union, Inc. 34 Wash App 708;664 P2d 1262 (1983). A declaratory judgment action was brought by Union Pacific Ins. Co. to resolve an insurance coverage dispute which arose following a massive gasoline leak at the insured's gas station in Seattle. It was determined that approximately 80,000 gallons of gasoline leaked out of a small hole in an underground gasoline pipe, over a period of some months, at the service station. The CGL Policy contained a pollution exclusion clause. The court found that the insurance policy was ambiguous and held:

> The insured in the case before us was not an active polluter. the gasoline leaking from a hole in the underground line was not expected nor intended, nor was the resulting damage. Thus, the pollution exclusion did not exclude coverage for third party claims and suits against the insured. To hold otherwise would permit the ambiguous pollution exclusion clause to unfairly devour much of the policy and relieve the insurer from liability clearly within the spirit and intent of the policy. (Emphasis added)

The Courts have uniformly held that the standard pollution exclusion is in need of further interpretation and thus ambiguous. The standard exclusion has been consistently interpreted to exclude coverage if the insured was an active polluter, or the occurrence was not sudden and accidental. According to recent legal definition, a spill is sudden and accidental when it is, or the resulting damage is neither expected nor intended from the standpoint of the insured.

In sum, the judicial interpretation of the phrase "sudden and accidental" has been so overwhelmingly favorable to the insured, that the exception has almost completely swallowed the exclusion. this legal climate has credited a sense of utmost concern among the entire insurance industry.

III. THE CHANGING MARKETPLACE

It is no secret that the soft market for commercial property and casualty insurance has disappeared almost overnight. After seven years of cutthroat competition for marketshare, company underwriters have embarked on a campaign to obtain substantial premium increases for all commercial lines.

The reasons for the demise of the soft market are fairly basic. Firstly, cash flow underwriting only works up to a point. Insurers have for some time been losing more money on their underwriting operations than they can earn on investments. It is estimated that property and casualty insurers suffered their largest loss in history during the 1983-84 underwriting cycle - $21 billion. This is the fourth year in a row that the industry has seen record losses. In addition, investment income failed to exceed underwriting losses by almost $4 billion. Consider the following statistics reported by A.M. Best Company:

- The combined loss ratio for the property and casualty business as a whole climbed to 118% last year. In other words, insurers collectively incurred $118 in claims and operating expenses for every $100 in premium collected.

- The combined loss ratio for commerical automobile insurance reached close to 130%.

- Workers' Compensation business was almost as staggering, with a combined ratio after dividends to policy holders of almost 123%.

- General Liability was worse, with a combined ratio estimated in excess of 150%.

Another major factor associated wtih the dramatic turnaround in the insurance marketplace is the reinsurance problem. During the past five years, reinsurers have also written business at unprofitable prices, primarily due to excess capacity.

In the 1970's, the reinsurance market was flooded with capital. this overabundance inevitably led to lower and lower pricing. Consequently, reinsurers got caught in the same cash flow underwriting game primary insurers were playing. That is to say, return on investments were being utilized to offset underwriting losses. However, reinsurers were soon caught in a double bind: primary insurers demanded excessive reinsurance commissions and credited reinsurers with low interest rates on their retained deposits.

The effects were felt in 1984 when many reinsurers faced with deterior-ating loss ratios and a decrease in investment income, decided to put an immediate halt to the "cash flow game". However, the sudden halt was out of necessity. At the reinsurance rendezvous in Monte Carlo last year, it

was widely reported that at least seven of the top 30 reinsurers were technically insolvent. In addition, during the past year, at lease six reinsurers stopped writing all reinsurance business while a number of others have stopped riting facultative and other types of reinsurance but have not abandoned the market entirely.

Consequently, when the time came to negotiate and renew reinsurance treaties at year end, primary insurers found a restricted market, higher pricing and a deep concern among reinsurers over the type and quality of busines submitted to them.

It is evident with further reinsurance treaties to be negotiated in April and July 1984 that capacity will continue to diminish and prices will continue to escalate. The long-term picture is also gloomy.

The Insurance Services Office (ISO), an organization established by the insurance industry to research and publish forms used by member carriers, estimates that there will be a capacity shortage of $62 million, mostly in the commercial lines.

The insurance marketplace for those companies involved in the Hazardous Waste Business is also dim. The Hazardous Waste Market also faces the problems associated with the reinsurance crunch: dwindling capacity, selective underwriting and price increases.

However, as previously discussed, the regulatory community has rightfully demanded that persons and companies dealing in hazardous materials demonstrate some type of financial capacity to pay for harm caused to the environment and third parties. It is obvious that the trend among legislators, as respects pollution coverage, is a broadening of parties held liable through statutes which ease the plaintiff's burden of proof through presumptions of causation and statutory enactment of strict and/or joint and several liability standards. Further, the trend in the judicial branch to award extradorinary damages in pollution cases and to interpret insurance contracts to cover <u>all damages</u> lends greater instability to the marketplace.

The instability and shrinking marketplace is best exemplified in the area of Environmental Impairment Liability (EIL). Prior to January 1, 1985, six companies were actively involved in writing EIL Insurance (EIL). The capacity of those carriers totaled approximately $100 billion. Shortly after the December 31, 1984 negotiation of reinsurance treaties, capacity had been reduced to less than $22 million with only one carrier actively writing this line of business. The withdrawal of the reinsurance market is primrily the result of disasterous pollution claims and the further possibility of long tail liability. The paranoia is further hightened by the judicial climate and the inability among underwriters to predict with certainty a potential pollution loss. The collapse also coincides with the deadly chemical leak in Bhopal, India, which again points to the magnitude and complexity of insuring a pollution risk.

In the meantime, the so called toxic tort litigation will continue to be the main courtroom attraction of the 1980's. The EPA has identified 20,000 hazardous waste sites and expects to clean up 2500 of these at a federal cost of $7.6 to $22.7 billion. Other estimates are even higher with Congress's Office of Technology Assessment claiming that the government may have to clean up more than 10,000 sites at a cost in excess of $100 billion.

In response to the increase in pollution liability claims, the Insurance Services Office (ISO) has recently completed a major revision of the Comprehensive General Liability (CGL) Policy scheduled for use in 1986. The proposed revisions would virtually eliminate <u>all</u> pollution coverage under the CGL Form. The new form would provide "claims made" coverage and add a retroactive date to the policy which would give underwriters the power to exclude coverage for bodily injury or property damage that occurred prior to a date selected by the underwriter. Essentially, on a claims made form, an insured's coverage obligation is triggered by the receipt of a written claim. The policy would also eliminate all pollution coverage stemming from insured's premises or ongoing operations on both claims made and occurrence form. However, an exception would be made for products/completed operations liability. For example: a company manufacturing air pollution control devices will still have coverage for any pollution damage caused by the malfunction of the device. A currently proposed, the new policy form would exclude coverage for liability for:

1) "bodily injury" or "property damage" consisting of or arising out of the permanent or transient contamination of the environment by pollutants, or

2) any loss, cost, expense or application incurred by, asserted against or imposed upon you or others arising from a governmental direction to test for, monitor, clean up, remove, contain, treat, detosify or neutralize pollutants.

Currently, the CGL Policy excludes coverage for:

"bodily injury or property damage arising out of the discharge, dispersal, release or escape of smoke, vapors, soot, fumes, acids, alkalis, toxic chemicals, liquids or gasses, waste materials or other irritants, contaminants or pollutants into or upon the land, the atmosphere or any watercourse or body of water. This exclusion does not apply if such discharge, dispersal, release or escape is sudden and accidental."

The majority of courts reviewing this provision, commonly referred to as the sudden and accidental pollution exclusion, have found it riddled with ambiguity. the problem with the interpretation of the pollution exclusion has generally centered upon the definition of the term "occurrence".

In 1966, the CGL Forms were revised to express their intent to cover "Occurrences" rather than "accidents". The definition of occurrence is:

> "an accident, including continuous or repeated exposure to conditions, which results in bodily injury or property damage neither expected nor intended from the standpoint of the insured".

It is basically this definition of occurrence, actually found in the insurance contract, that has raised the controversy as to whether a gradual-type pollution incident is included as part of the CGL Policy. It was obviously the intent of insurance companies to exclude in the CGL Policy, pollution events occurring over the course of time or on a gradual basis. However, as previously discussed, courts have consistently construed the pllution exclusion to provide full pollution coverages where the pollution was neither expected nor intended from the stanpoint of the insured. In actuality, it becomes evident that the pollution exclusion is not much of an exclusion at all. Consequently, under the new ISO form, all pollution coverages will be excluded, and the insured will be forced to add pollution-type coverage by endorsement for a negotiated premium. It is believed that this is the only insurance mechanism available to handle the potential long tail liability associated with pollution-type claims.

IV. CONCLUSION: FUTURE EXPECTATIONS

As indicated, the market for Pollution Liability, both direct and reinsurance, is tightening, thus reducing capacity available to most independent carriers. In addition, premium levels are increasing on renewal, another sign of shrinking capacity.

Insurance has traditionally been an industry controlled by supply and demand. When the supply increases, the competition becomes intense as has been the case over the last five (5) years. However, the supply is now shrinking, and the demand is dramatically increasing causing prices to rise. This situation does not appear to be of short duration. The problem was obviously apparent with the renewal negotiations of reinsurance treaties that expired on December 31, 1984. During the past five to six eyars, the reinsurance market has suffered extensive losses on casualty business due to the extreme pressures exerted by competition and overcapacity. Currently, claim costs have caught up to the markets, thereby reducing operating income returns and causing severe combined loss ratios. The result of the above is that the rinsurance market is becoming increasingly more conservative in their underwriting philosophies.

In addition, such newsworthy and catastrophic events such as Times Beach and Love Canal have caused a further reluctance among insurance carriers to underwrite hazardous waste accounts.

The need for insurance in reference to companies involved in the Hazardous Waste Industry is certainly increasing. In accordance with the Motor Carrier Act of 1980, Liability Limits, for transporters of certain

classes of hazardous waste were increased to $5 million effective Janaury 1, 1985.

The need for EIL coverage is certainly increasing. Pursuant to the requirements of the Resource Conservation and Recovery Act (RCRA), certain clases of treatment, storage and disposal facilities were required to carry gradual pollution coverage effective Janaury 15, 1985. This creates pressure on the existing shrinking marketplace to provide such coverage. In an attempt to meet this increasing demand, more placyers must enter the marketplace.

Certainly, the perception of the insurance industry as a source of funding for cleanup is an accurate one. However, the legislative regulatory and insurance community must put aside their long adversarial relationship in an attempt to effectively assist with our nationwide pollution problems.

Environmental Compliance Services, Inc. (ECS) is a company specializing in insurance programs designed for organizations involved in the Hazardous Waste Industry. ECS is a managing general agent for the National Union Fire Insurance Company, a member of AIG. ECS provides jthe only nationwide program of insurance exclusively designed for the Hazardous Waste Industry and is endorsed by the following national associations:

- Hazardous Waste Services Association (HWSA)
- National Association of Solvent Recyclers (NASR)
- Association of Petroleum Re-refiners (APR)
- Spill Control Association of America (SCAA)

For further information, please contact David M. Rosenberg, Esq., at Environmental Compliance Services, Inc., P.O. Box A, Downingtown, PA 19335, telephone within Pennsylvania (215) 269-6731, outside Pennsylvania (800) ECS-1414.

MICROCOMPUTERS FOR TRACKING
HAZARDOUS MATERIALS EXPOSURES IN THE WORKPLACE

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Many companies must now document exposures by their employees to hazardous materials for a variety of regulatory, liability, and labor relations purposes. Records of this information must be managed and made available to workers upon request. For medium to large businesses tracking via computerized databases is far more cost-effective than manual record keeping. For many installations, exposure database management can be performed on microcomputer systems, thereby realizing cost savings and permitting creative database manipulation by "non-computer professionals." Hardware and software requirements are defined by the numbers of employees, hazardous materials, and workplaces to be tracked and by the types of reports and data analyses desired. Selection criteria are given for specifying the most appropriate data management system, whether pre-packaged or custom design products are to be implemented.

INTRODUCTION

Goal today is to discuss recordkeeping tasks that can be done on micros then to examine important selection criteria for adopting a system.

Content of talk:

1. Reasons of keeping exposure records... In particular Cal OSHA's requirements.

2. Manual vs Computer and Microcomputer vs Mini or Mainframe.

3. Selection Criteria.

4. Examples of useful related utilities.

My experience involves dBASE II and III on a IBM PC/XT with 1 floppy, a 10 megabyte hard disk and 750k RAM...thus talk may be slanted to that configuration but similar systems should be as suitable.

For ease of speaking when referring to chemicals, products, intermediates, raw materials, wastes, as well as physical exposures such as noise, vibrations, heat, repetitive motions, etc. are included.

REASONS TO MAINTAIN EMPLOYEE EXPOSURE RECORDS

1. Comply with laws and regulations, eg Section 3204 of General Safety Orders, Title 8 California Administrative Code.

2. Monitor injuries and hopefully contol future rates and severity.

3. Mitigate potential liabilities...dual capacity as employer with duty to not provide employees with safe work environment and as a manufacturer of a hazardous product (products liability). This is new, formerly only worker's compensation cause of action.

4. Social responsibility.

5. Reporting to labor union.

6. Reporting to insurer.

7. Peace of mind...reduce anxiety..

ACCESS BY WORKERS

Section 3204 of Title 8 of CAC specifies that employee exposure and medical records must be made available to employees or their

representatives on request and must be maintained for 30 years.

Employee exposure records include:

1. Workplace monitoring/measuring results including supporting information;

2. Biological monitoring results that directly assess the absorption of a substance or agent by body systems... chemical levels in blood, urine, breath, hair, fingernails, etc.

3. Material safety data sheets:
    1. incl. identification
    2. ingredients
    3. physical data
    4. fire and explosion hazard data
    5. health hazard data
    6. reactivity data
    7. spill or leak procedures
    8. special protection information
    9. special precautions

Employee medical records include:

1. Medical and employment questionnaires or histories (including job descriptions and occupational exposures)... results of medical exams and lab results;

2. Medical opinions, diagnoses, progress notes, and recommendations;

3. Descriptions of treatments and prescriptions;

4. Employee medical complaints.

MANUAL vs COMPUTER and MICROCOMPUTER vs MINI or MAINFRAME

1. Paper in notebooks and filedrawers is inadequate for maintaining and reporting workplace chemical exposure data.

2. Flexibility of data use and reporting with computers. Data can be entered once yet used in a number of contexts...it is not tied to a specific application. This fosters adaptability to changing business needs and regulatory mandates.

3. Permits manipulating data across process or facility (geographical) boundaries.

4. Speed...Reduces time and effort for responding to management inquiries.

5. Data integrity is improved by error checking on entry...alpha, numeric, ranges, dates.

6. With respect to micro vs larger machine:
    1. Availability of system with less down time given multiple machines.
    2. Speed
    3. Storage

SELECTION CRITERIA

1. FIRST, Crystalize organizational profile before selecting from potential alternative solutions:
    1. identify responsibilities and reporting relationships of all involved units:
        1. IH
        2. medical
        3. personnel
        4. purchasing
        5. environmental
        6. DP
        7. security
        8. payroll
    2. characterize all information management objectives to be met:
        1. agency or in-house user
        2. number of records
        3. frequency of updating
        4. report type(s)
        5. frequency of reporting
    3. catalog all relevant reports now prepared
        1. department level
        2. interdepartmental
        3. reports to upper management
        4. regulatory agencies
        5. insurance companies
        6. industry associations
    4. inventory existing resources to be built upon
        1. DP hardware and software
        2. systems expertise
        3. structure of existing data bases

2. Data base management system not spread sheet for most purposes... Record management not computations.

3. Must relate people (employees) with workplaces (exposures) with time periods.

4. Must track unique areas of plant with respect to specific exposure spectra. This could range from a whole building to a single workstation. The essence is to treat the same all employees exposed to the same conditions. If each employee's exposure is truly unique, the functional definitions of "work area" and "employee" merge.

5. Must track hazardous chemicals as individual materials as well as when components of mixtures...plus the mixtures must be tracked as entities because of nonadditive effects of

simultaneous exposure to multiple chemicals, eg. synergism and antagonism

6. Must track changes in employees' status with time...hire, position change, leave, termination, etc.

7. At a minimum, the system must respond to 2 queries:
   1. who was exposed to XYZ (chemical) during a time frame.
   2. what chemicals was ABC (employee) exposed to during a time frame.

8. Must be reasonably compatible with existing information flows within the organization.

9. Interface with other computers used to manage associated data bases.

10. Should complement related information management tasks: hazardous waste and PCB inventory tracking, manifest preparation, generator annual reporting, and spill incident logging/reporting.

11. Data file configuration capabilities....amount and types of information per record.
    1. MSDS entry has about 2k with abbreviations but no coding... therefore about 180 on a floppy disk.
    2. coding can reduce file size dramatically but adds overhead in response time and limits choice of descriptors.
    3. alternative approaches to managing large variable records not subject to summary reporting:
       1. Embody entire mass of information into system
       2. Enter only quantifiable and encodeable information with narrative information simply indexed.

12. File size capacity...number of records
    1. hard disk is required for all but smallest systems
    2. for larger installations with many locations, employees, or workers, a micro will be insufficient.

13. Process in speed...interactive and batch (overnight)
    1. Queries should be instantaneous (matter of seconds)
    2. Summary reports may take longer (overnight)

14. Hardware requirements
    1. number and size of drives, ram, i/o devices
    2. Capital cost
    3. O and M cost

15. Reporting capabilities...ad hoc and defined. Must present data at several levels of aggregation
    1. in whole form for day-to-day use locally
    2. facility or corporate summaries for upper management.

16. Expandability to accommodate different additional:
    1. workplace environments
    2. employees
    3. chemicals
    4. changes in regulations.

17. User friendliness
    1. unintimidating
    2. easily learned...menu oriented
    3. not too sticky sweet for daily use

18. Security...accidental or intentional corruption of data
    1. fire
    2. sabotage
    3. system use error

19. Implementation time frame

20. Vendor support

21. Bells and whistles

EXAMPLES of SUPPLEMENTARY TASKS VALUABLE to NON-PROFESSIONALS

1. Scheduling for monitoring, sampling, and reporting

2. Synonym handling...automatically references any chemical or material name to a CAS, RTECS, or other suitable, unambiguous nomenclature. This should be tailored to include all products, intermediates, feed stocks, byproducts and wastes encountered.

3. Chemical compatibility screening. Can determine all incompatible combinations of chemicals used by an organization or identify all materials at a location that are incompatible with a given material.
    1. Based on "A Method for Determining the Compatibility of Hazardous Wastes" EPA-600/2-80-076 by CA DoHS group lead by Howard Hatayama.
    2. Divides materials into one or more of 41 "Reactivity Groups"...non-oxidizing mineral acids, oxidizing mineral acids, organic acids, alcohols and glycols, aldehydes, etc. For example methyl isocyanate is classed in 2 groups: isocyanate and water reactive substance.
    3. Potential reactions from binary combinations of the groups are identified as:
        1. heat generation
        2. fire
        3. innocuous and non-flammable gas generation
        4. toxic gas generation
        5. flammable gas generation
        6. explosion
        7. violent polymerization
        8. solubilization of toxic substances

9. unknown.

4. Multiple possible reactions may apply: heat generation followed by fire followed by toxic gas generation.

OFF-THE-SHELF vs CUSTOM

1. BIG question:
    1. purchase prepackaged software
    2. develop from scratch
        1. inhouse
        2. consultant
    3. tailor commercial package written in accessible language, eg dBASE

2. Time element

3. Sacrifice efficiency and performance with many inapplicable features or excess capacity (bells and whistles).

SUMMARY

Adoption of any employee exposure tracking system should be with the full and explicit support of top management with resolve to commit effort needed. This will involve both first cost and time as well as continuing cost and effort.

A useable system Must provide a basis for decisionmaking. This can involve trend analysis or ready comparison with historical records.

TIMELY ACCESS TO COMPREHENSIVE HAZMAT INCIDENT INFORMATION

AN OPPORTUNITY
TO CREATE A FLEXIBLE, COMPUTER-BASED INCIDENT REPORTING SYSTEM

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ABSTRACT

The frequency of accidental releases of hazardous materials (hazmats) into the environment appears to be sharply increasing. At present no one knows with any certainty how many such incidents are managed by public agencies, much less exactly how many actually ocur. Little or nothing is known about the conditions under which hazmat accidents take place, and the long term public health risks resulting from them remain undocumented. In short, there is no comprehensive statistical information to guide the management of public resources in response to this threat. The magnitude of the adverse effects of these substances mandates a management approach more substantial than the conjecture arising from opposing points of view. A unified, evolving, inexpensive Hazmat Incident Reporting System (HIRS) would effectively guide legislation and public policy at state and local levels. This paper seeks to stimulate and facilitate the implementation of such a system. The net result will include significant improvement of the general quality of life and a savings of life and property due to better planning and public safety practices.

FIRST PRINCIPLES

The primary purpose of a reporting system is to provide managers with the information they need to better understand the nature of the challenges they face and to clearly determine the most appropriate alternative responses.

An important secondary purpose of a reporting system is to facilitate discussion and cooperation among all concerned.

A good reporting system has several qualities. These include:

1. COMPREHENSIVENESS. It is designed to seek out and accept all of the appropriate data.

2. ACCURACY. It is accurate in its summarizations.

3. TIMELINESS. The information it produces arrives in the hands of management in time to be of greatest use.

4. USEFUL TO ALL KEY PEOPLE. The information produced by the reporting system is useful to all those who play necessary roles in its operation.

5. ILLUCIDATIVE. It draws attention to the sources or causes of problems facing management.

6. SUGGESTIVE. It suggests the most appropriate alternative courses of action.

7. COST-EFFECTIVE. It produces benefits worth more than the costs associated with it.

8. ACHIEVABLE. A reporting system must exist within the framework of ALL of the organizational constraints that effect its implementation, development, and survival.

FIRST PRINCIPLES APPLIED TO A HAZMAT INCIDENT REPORTING SYSTEM

In light of the above partial list of report system qualities, what would a hazmat incident reporting system specifically entail? It would be comprehensive in its data gathering within a clearly stated area. For example, it would draw information from ALL agencies charged with incident management within a county, region, or state. It would be accurate in its tabulations. Those managing the HIRS would produce and distribute reports on a schedule that allowed all managers involved to use the information. The HIRS would produce the kind of information that is of use to managers in the lower jurisdictional tiers as well as at the regional or state levels. Because we are at a very early stage in our attempts to manage the problem of accidental hazmat spills/releases, the reporting system must allow managers to quickly rearrange the report format and, in effect, "hunt" for key factors. This is the only way we are likely to discover the sources or causes of hazmat incidents and the most appropriate counter-measures. The ideal hazmat incident reporting system would seek to minimize its cost by integrating easily into the existing response system and by requiring a minimum of additional time to maintain. Finally, our HIRS would have to fit into the way many different agencies at different jurisdictional levels conduct their activities.

This very general description gives us a starting point from which we may begin to refine and further describe the character of a successful HIRS. Several HIRS design concepts suggest themselves immediately:

1. In order to be useful to managers at the regional and state levels, the Hazmat Incident Reporting System must be centrally focused. That is, at least some of the information collected must flow into a central location for processing and examination. Ideally, only that information

generally considered useful at the regional or state level would be forwarded. To accomplish this, the region-wide and state-wide information should be easy to separate from the information useful only at the local and/or agency level.

2. In order to maximize the timeliness of reporting and the flexibility of the report format, the system should be computer-based and specifically allow partial processing by microcomputers at the local agency level. The volume of data generated by this reporting system and the need to create new report forms to test hypotheses mandates the speed, accuracy, and flexibility available only from computers. The use of computers, and microcomputers in particular, will also allow local managers the freedom to experiment with their incident data and hunt for important factors independent of the data processing activities at higher jurisdictional levels.

3. As a general rule, the likelihood that a proposal will be implemented IN TIME TO BE USEFUL is inversely related to the number of people who must reach concensus on the details of the proposal itself. This is particularly true regarding the comprehensive implementation of an HIRS. As mentioned earlier, agencies at different jurisdictional levels are interested in different types of information and different levels of detail within the same type. This makes it highly unlikely that all agencies at all jurisdictional levels would be able to agree on a single data collection form. A data gathering approach must be developed that provides benefits to every jurisdictional level and every agency therein without "tying" each to the informational needs of others.

   This can be accomplished by creating a segmented form in which each segment reflects the needs of each juisdictional level. Each jurisdictional level would have complete freedom to create and evolve its segment. For example, the HIRS form on the front seat of a San Diego City Fire Department vehicle would have three sections: 1) the basic one-page form used state-wide, 2) the one-page San Diego County addendum to the state form, and 3) the San Diego City Fire Department addendum to the state and county sections. This three-page form could be photocopied and sent to three different offices where the sections could be separated if desired and used for data entry. Because sections 2 and 3 are addenda, a particular piece of information only has to be written once by the incident commander.

A STATE-WIDE HAZMAT INCIDENT REPORTING SYSTEM

With the above concepts in mind, how would a state-wide HIRS be structured and how would it operate? Broadly speaking it would

consist of a three-part incident data gathering form. Section "A" would be a state-wide form designed by the state-wide agencies concerned with hazmat incidents in conjunction with members of a separate body charged with the care and development of the HIRS in its entirety. Section "B" would be a county-wide form developed by interested agencies within each county. Representatives from the interested county agencies would be encouraged to draw assistance from the state-wide HIRS management body. Section "C" would be a form designed by the local incident managing agency.

The HIRS managing body could provide technical support and assistance in the development of data management software. This body might even do the data processing for the state level report. In California, a task group within Firescope or its parent, Office of Emergency Services, might fullfill this role. Periodically, the state-wide agencies might modify their form. County and local agency HIRS committees would time their reviews accordingly. The HIRS managing body would work to develop new report forms and act as a clearing house for report software and insights developed by others. Periodically this HIRS managing body would produce the state-wide reports designed by the state committee and distribute it throughout the state for review and comment.

A SAMPLE HIRS INFORMATION GATHERING FORM

An example HIRS data collection form is available on request as Appendix "A" to this paper. It is intended for illustrative purposes only. The example was developed from an analysis of a large sample of hazmat incident report forms already in use in California. It includes the three sections mentioned above: state, county, and incident command agency. It also includes a cover sheet that documents requests from other response agencies for copies of the completed form. For example, the U.S. Coast Guard might be called in on an incident and want a copy of all three sections to assist in their administration. The cover sheet allows the incident commander to note their request in a way that can be acted on by the secretarial staff at headquarters. Several other aspects of this form are worth particular mention:

1. Each of the three sections begins with a three-part incident identification number. The third part of this number is assigned by the HIRS managing body over the telephone during or shortly after the emergency response phase of the incident. The overall number is designed to allow for the instantaneous production of incident totals for a particular county or group of counties, month or group of months, year or group of years, year to date, month to date, and any combination thereof. This number vastly streamlines the generation and comparison of simple frequency-of-occurence statistics.

2. The county and local agency HIRS Committee phone numbers are to be filled in on the state-wide form. This, in

conjunction with the incident identification number, provides a clear audit trail for anyone at the state or county levels seeking additional information on a particular incident.

3. The state, county, and local agency sections of the form generally follow the same format. Each asks for information regarding the scene, the hazardous material involved, the incident itself, the risk to responders and the community, the action taken, and the damage done. This assists the county committee in determining what was not included on the state-wide form that is important to them. Likewise, it assists the local agency HIRS committee in determining what of importance was not included in the state-wide and county-wide sections. The HIRS managing body should work with all HIRS committees to maintain useful common categories and to determine the best data category for a particular piece of information.

4. In general, the HIRS data gathering form is designed to capture pieces of a specific type information; information that can be statistically summarized. This is true because numbers are the only way a manager can sense the magnitude of patterns and trends. However there are at least two exceptions. A "human damage roster" is attached to the county section that lists the names and personal information of all persons exposed, injured, hospitalized, and killed in the incident. Secondly, a portion of the local agency section is devoted to how the incident could have been prevented and handled better by all involved.

For information on how to receive a copy of the example HIRS data gathering form, please contact Eric Hutchins at (619) 292-0323. Also your opinions and ideas would be greatly appreciated by those associated with this project.

FAST EMERGENCY ACCESS TO ACCURATE HAZMAT INFORMATION

AN OPPORTUNITY TO UTILIZE THE SPECIAL RESOURCES OF THE REGIONAL TOX CENTER AND THE STRENGTHS OF MICROCOMPUTER TECHNOLOGY

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ABSTRACT

In California, the number of incidents involving hazardous materials appears to be increasing. With this increase there is a growing concern among public agencies and private corporations about how to better prevent such incidents and how to more effectively control those that do occur. Accurate, quickly accessible information on the nature and handling of hazardous substances is an important part of the answer to both questions. At present there are numerous sources of hazmat information. However the accuracy of this information is unclear and often unverified. Secondly much of the information published is not in a form that is readily usable or accessable by plant safety engineers, incident preplanners, and on-scene incident commanders. This paper describes a phased program that will provide rapid and reliable access to accurate information on hazardous materials for all concerned parties. The program augments the special resources already in place with proven microcomputer and communications technology.

Preventing accidents and minimizing the damage of those that occur are important concerns of both industry and government. Plant health and safety people along with those charged with public safety desperately need a reliable, accessible source of accurate information regarding the character and safe handling of hazardous materials. Such information would show those concerned where to look for trouble, what steps to take and, should an incident occur, what situations are likely to confront an on-scene commander.

By its nature much of this needed information is dispersed across many disciplines including several branches of chemistry, toxicology, cellular biology, and environmental sciences. Some of it is learned the hard way and at great expense in ambulances and emergency rooms. The information needed must be validated and reorganized from the way it presently appears before it can be used by those concerned with prevention. The same must occur before published information can be used by those responding to hazmat incidents that do occur.

The ideal solution would:

1. Provide industry and government with one outstanding source

of readily accessible information. This source should be in a position to continuously review information from all publications and, informed by practical experience, consolidate it into a concise form that is readily usable.

2. Include an excellent information delivery system with enough built-in redundancy to insure that the information is always available to those who may require it.

3. Preserve the proprietary rights and interests of industry while satisfying the "need to know" requirements of public agencies and the "right to know" of the public at large.

4. Demonstrate itself to be an irresistably good investment for all responsible for prevention and incident control.

We believe that the quickest and best solution to the informational needs of all concerned is <u>BUILT ON</u> the existence of an energetic, regional toxicological information center funded in a variety of ways by the public and private organizations it serves. A regional "Tox Center" would be readily accessible to the groups it serves and its survival would be directly linked to the quality of the services it offers.

We believe that the quickest and best solution is <u>ACHIEVED</u> by utilizing proven, relatively inexpensive microcomputer and data communications technology. Specifically, this technology would be used to recreate portions of the electronic database developed by the Tox Center within government agencies and industrial plants. The Tox Center "parent" database would be under constant expansion and re-examination. The "satellite" databases located at sites throughout industry and government would be periodically updated with information from the parent.

The satellite databases would come to function as a first source or "tier" of information available to those needing it. The on-call staff of the Tox Center would become the back-up, or second tier. The Tox Center would be in constant, routine communication with national hazmat databases which would form a third tier of information.

Under this approach, the Tox Center, government agencies, and private corporations would all share the same electronic format or "software file structure and access utilities". However each would retain complete operational control of the actual chemical information contained in their individual copy of this software.

This would allow industry, for example, to receive and merge information on a long list of standard substances from the Tox Center and then add information to it on their own proprietary list. In this way, an industrial plant manager could maintain a complete inventory of substances stored and used in his facility along with important information on safe handling, toxicology, and medical treatment, without compromising proprietary

interests. Should an incident occur, the plant manager could supply vital information to the on-scene commander regarding the safe handling of the substance involved.

Besides providing two rapidly accessible tiers of accurate chemical information, a Tox Center could provide both industry and government with consultant services. These services would encompass both preventative pre-planning and control activities during an incident. An energetic Tox Center would also provide a neutral, on-going forum where all concerned could air differences and work together to better achieve common goals.

The following table summarizes a phased program for developing the information system described above. During Phase 1, the Tox Center, regional response agencies, and other support groups establish microcomputer workstations on which the hazmat database generated by the Tox Center is to be maintained. Communications between all groups would be achieved by telephone or existing radio voice links. Software would be updated by the transmittal of digital recording media (floppy disks). The on-scene commander would rely on his agency's dispatcher for hazmat information. If the incident is at a fixed facility participating in this program, the plant safety engineer, or other company representative, would be expected to support the incident commander as well.

During Phase 2, the Tox Center would go on-line to allow access to their master database. This database would contain substantially more substances than stored in satellite databases running on less expensive equipment. Response agencies would also go on-line to the incident commander at the scene. This would allow the incident commander direct access to information in his agency's satellite hazmat database or a separate occupancy database by means of a "briefcase-sized" portable microcomputer. It should be mentioned that the technology for both Phase 1 and 2 presently exists and is in operation in other areas of the country.

We believe that the presence of the Northridge Tox Center makes the establishment of the information structure outlined above achievable in the near term. The Center has completed the development of the needed software and is preparing to load the necessary chemical information into it.

Those interested in further discussing the ideas presented in this paper, are invited to contact either Dr. Doug Arterberry of the Northridge Tox Center or Mr. Eric Hutchins of Emergency Data Systems, the software contractor to the Tox Center.

Table 1.1 Phased Deployment of Computer/Digital Communications Technology to Enhance the Speed and Reliability with which accurate Hazmat Information is Available to the On-Scene Incident Commander

INFORMATION RESOURCES/USERS	PHASE 1	PHASE 2
National Resources Resources in other Regions	Electronic/Hardcopy Databases and Experts	
Communication Link	Voice/Data Telephone	
Regional Toxic Substance Information Center (Northridge Tox Center)	Qualified Medical Specialist Add Off-Line Computer Database	Add On-Line Computer Capability
Communication Link	Voice Telephone	Add Data Telephone Link
First Response Agencies (Fire/CHP)	Dispatcher Add Off-Line Computer Database	Add On-Line Computer Capability
Communication Link	Voice Radio	Add Cellular Telephone Data Link
On-Scene Incident Commander	Voice Radio	Add Briefcase Computer Terminal
Communication Link	Voice Radio/ Messanger	
Support Agencies (Area Hospitals) Support Agencies (Corporate Safety Staff)	Emerg.Rm./EMS Dispatch Add Off-Line Computer Database Plant Safety Personnel Add Off-Line Computer Database	

COMPUTER APPLICATIONS FOR ENVIRONMENTAL DATA COLLECTION AND MANAGEMENT

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ABSTRACT

This paper examines some of the reasons why environmental data management (EDM) has not been extensively computerized and why computerization is becoming an increasingly common and necessary way to manage environmental affairs. The specific benefits of computerized vs. manual EDM are discussed and an overview of the types of available software is provided. Finally, various approaches on how to proceed with the development and implementation of an EDM system are reviewed. Actual case-study examples will illustrate a company with a system in the planning stages and another company that has previously installed an EDM system.

INTRODUCTION

Economics have forced other businesses facing increasing administration data management challenges to computerize years ago. The transition to computerize data management systems in industries such as banking, securities trading, insurance, manufacturing, retailing and travel is so complete that these businesses literally could not operate competitively without such systems. Ironically, economics has kept many environmental departments from implementing data management systems sooner.

Although environmental regulations have existed in some shape or form for many years, it was not until the 1970's that a well-defined environmental regulatory policy came into being. Over the last 15 years, more and more people began to accept the cost of environmental compliance as a fact of doing business. This cost of compliance was, and in many cases is still, viewed as "overhead" or not contributory to the "bottom-line." Accordingly, little was spent in the way of automating environmental affairs. However, environmental affairs management has recently catapulted to the forefront of issues facing business and government.

Environmental Affairs Managers are facing increased pressures to implement ever-toughening regulatory programs and document compliance with the law. On the other side of the regulatory fence, governmental agencies are being called on to investigate, analyze, review and regulate an increasing number of activities. Both government and industry are faced with tight budgets, increased responsibilities, and the need to better manage available resources.

The print and electronic media have been giving environmental news items headline status. Individual citizens, politicians, as well as those qualified and unqualified to speak out on environmental issues have been doing so in ever-increasing numbers. This growing awareness and concern regarding the management of environmental affairs compounds the pressures being placed upon those individuals who must maintain, as well as enforce, environmental compliance.

No one will disagree that it is in the public's interest to track, record, review and report environmental data, and that regulatory programs need to be efficiently administered; however, the logistics of accomplishing all of this is rapidly moving beyond the scope of what can reasonably be expected through the use of manual techniques currently being used. Computerizing environmental data management is one of the measures that more and more companies and regulatory agencies are taking to improve the efficiency of their environmental staffs and ensure that their technical expertise will be available when and where it is needed most.

BENEFITS OF COMPUTERIZING

Computerization can benefit almost all areas of environmental data collection and management. Computers can very efficiently store and permit rapid, reliable and flexible retrieval of huge amounts of data because of the centralized data base and data quality control features inherent in an automated system.

Centralized Data Base

Creation of a centralized environmental affairs information data base can allow a wide variety of access, and report generation options for the user network. Much of the data, once initially entered, can be used repeatedly for different environmental functions. Information can be entered at each facility and manipulated for day-to-day use. Summary information can be accessed by managers with multi-facility responsibility, and trend and statistical analysis capability can be provided by which to identify problem areas or to compare facility performance profiles.

Control of Data Base Quality

In a manual system, errors may go undetected until a problem develops, at which time a correction based upon error reconstruction may be time-consuming or even impossible. Automated systems enable data to be checked for validity and correctness at the time of entry. Menu prompting messages can ensure that data is entered in the proper locations consistently and that the data required to be entered is complete. Such features reduce the need for proofreading by management and also lessen the chance for errors made by new employees in the event of turnover.

The following provides brief examples of specific benefits in the major EDM functional areas.

Emergency Response

Spill response procedures, including underground tank leak response procedures can be entered and updated on a computer and accessed by any employee at anytime round-the-clock.

Monitoring Data for Permit Compliance

With existing manual systems, much data currently is monitored and recorded periodically on log sheets and is later analyzed for compliance with permit limits and compiled into compliance reports, such as those required by NPDES. Such periodic log sheet data can be entered directly at a computer terminal at which time a comparison can be made with permit limitations and any non-compliance recorded by the computer for later action. Periodically, compliance reports could be requested in which the log data would be processed to yield the required minimum, maximum and average values required in an NPDES report. All other air, effluent, and groundwater monitoring can also be included and summary reports generated by facility and monitoring points.

Regulatory Requirements

Specific regulations from state and federal statutes which are applicable to specific facilities or specific operations within a facility can be easily accessed and updated.

Permit Tracking

Permits periodically require renewal and sometimes modification. A comprehensive permit listing for all substances and process operations for each facility can be easily maintained and accessed. Tickler reports can be generated for renewal of permits well in advance of the expiration dates. Actual permit requirements can be logged into the computer, and closed out upon completion.

Waste Tracking

Efficient tracking of hazardous waste shipments is particularly important for generators of these wastes since they retain liability for transport and ultimate disposal. Waste type, volume, transporter/disposer, permit numbers, and shipping, disposal and manifest return dates can be entered for all onsite and offsite shipments from each generating facility. Tickler reports can be generated listing manifests due to be returned in advance of due dates. Listings of overdue manifests can similarly be generated for regulatory reporting and followup action. Other reports summing totals of waste generated and disposed of by waste type, generating facility and disposal facility would also be available. Creation of annual generator reports would require minimal resources since all required data would already be on the system and would be manipulated by the computer as opposed to manual file searching and compilations.

Chemical Inventories and Handling

A complete listing of chemicals and quantities, including permit limits and specific locations, can be entered and maintained for each facility. Where available, Material Safety Data Sheets (MSDS) and storage, handling and disposal procedures can also be entered, and updated as necessary. Access to all the above information for each chemical could be accessed quickly and easily on a round-the-clock basis.

PCB Equipment

The inventory of all PCB-containing transformers and capacitors can include concentration, volume, location, serial number, rating, manufacturer, and dates of installation, storage and disposal for each piece of equipment. Data can be entered, updated and accessed as necessary to produce TSCA reports on transformers in/out of service, capacitors in storage, and volume of PCBs disposed of.

Hydrocarbon Storage Tanks

The data required by EPA document AP-42 for calculating storage tank emissions can be entered and updated accordingly. Reports can be generated listing the standing and working emissions for each tank and the amount of emissions that could be offset by changing tank seal/color characteristics.

Fugitive Hydrocarbon Emissions

Information on valve and pump seal emission sources such as emission type, location, service type, test date, emission volume, repair date, retest date, and retest emission volume can be entered and updated. Reports can be generated to list summaries of test repair, and retest data for all sources by facility.

Bulk Storage Tracking

Data on underground tank level measurements can be entered and automatically corrected for ambient temperature/humidity and reconciled with volumes of input and withdrawals since the previous level measurement. Similarly, tank inspection and testing schedules can be entered and tickler reports generated listing tanks which are due for retest or reinspection. Reports can also be generated listing the inventories of all tanks by facility or by chemical contents.

Incident Reporting

All environmental incidents such as spills, permit non-compliances, overdue manifests, test/inspection corrective actions can be entered, updated and closed-out as required. Incident reports can be logged automatically for spills, monitoring non-compliances, overdue manifests, and test/inspection findings, at the same time these functions are accessed. The computer automatically checks, for instance, water monitoring data at the time of entry with NPDES limits and if the limits are exceeded, will automatically create an incident report, identify the responsible party via his computer access code, the date, time, and type of incident. Reports can be generated listing all open incidents by facility, incident type, incident date, or responsible party.

In addition to the technical benefits noted above, computerizing can virtually eliminate the potential for regulatory citations for overdue manifests, overdue non-compliance corrective actions, permit expirations, etc. An EDM system could also reduce insurance premiums for liability coverage as a result of more effective management practices.

SUMMARY OF AVAILABLE SOFTWARE

There are a number of software packages developed specifically for one or more of the aspects of EDM noted above. Many of the available packages were developed for microcomputers, while others were designed for mini- and mainframe computer systems. In general, for single-facility applications, a microcomputer system may be ideal. For multi-facility applications, where facilities are separated from the central headquarters, a mini- or mainframe system may be more practical. Software may be purchased "off-the-shelf," or may be customized to company-specific specifications. Of course, there is always the option to design and implement software for specific applications essentially from scratch, either in-house or using a consultant. Table 1 provides a listing of some software packages with a brief description of EDM functions addressed by the packages. This listing is intended to provide an overview and is not intended as a

intended as a selection guide, nor does it list all available environmental software. Guidance on how to implement an EDM computer system is provided in the next section of this paper. Most of these software packages were described in more detail in the January 1985 issue of Pollution Engineering, which may be consulted for further information.[1]

TABLE 1

HAZARD/IBM PC
- Manifest Tracking

ECOTRAC/IBM PC
- Permits Tracking
- Source Inventory
- Environmental Events
- TSCA Required Data Management
- Groundwater Monitoring
- Manifest Tracking

FLOW GEMINI/DEC VAX[2]
- Permit Administration
- Air and Water Monitoring
- Waste Tracking
- PCB Inventory Management
- Problem/Event Management

HASTE/Unspecified Micro and Minicomputers
- Emergency Response to Air/Water Spills
- Realtime Meteorological Spill Analysis

APE/IBM, Radio Shack PCs
- Air Pollution Emissions Monitoring

APCECOST 1.1/IBM, Radio Shack, Apple, Kaypro PCs
- Cost Estimation for Air Pollution Control Equipment

ANASOFT/IBM PC
- Monitor Flows, pH, Pollutant Levels
- Recordkeeping
- Alarm Functions
- Input/Output with Anafaze 8 MCS Hardware

CHARM/IBM PC
- Predict Location, Concentration and Extent of Toxic Release Cloud

CAMEO
- Process Control Data Management
- Maintenance Management
- Energy Management
- Industrial Waste Management

RODA
- Records and Data Management
- Governmental/Operational Reports
- Summaries
- Trend Analyses

DATASTREAM/IBM PC

- Wastewater Treatment Plant-Specific
- Data Management
- Report Pac
- Stat-Graphics Pac
- Performance Pac

OPERATOR 10

- Wastewater Treatment Plant-Specific
- Industrial Pollutant Monitoring
- Inventory Management and Maintenance
- Process Monitoring NPDES Reporting

Environmental Ledger Series/IBM PC

- Material Safety Data Sheets
- Chemical Spill Procedures
- Emergency Services
- Hazardous Materials Inspection
- Underground Storage Monitoring
- Chemical Inventory
- Incident Documentation

Suneco/Unspecified Mainframe[3]

- Environmental Permits
- Water Monitored Data
- Hydrocarbon Storage Tanks
- PCB Equipment
- Fugitive Hydrocarbon Emissions
- Environmental Incidents
- Hazardous Waste Manifests
- Groundwater Monitored Data

QUADREX EAMS/IBM Mainframe

- Spill Emergency
- Chemical Handling
- Incident Reporting
- Monitoring Data
- Regulatory/Permit Requirements
- Manifest Tracking
- Bulk Storage Monitoring
- Trend Analysis
- Plant Functions

DESIGN AND IMPLEMENTATION OF AN EDM SYSTEM

As described in the previous section, there is a considerable amount of software available with a variety of functional and hardware compatibility. The selection of a particular software package or the decision to develop a custom-built system will depend upon the nature of a user's operations, its size, number of facilities, existing hardware configuration, and existing manual data management systems. Implementation can be effected on a piece-by-piece basis, in which existing manual EDM functions are automated individually one function at a time. Two types of software packages facilitate this approach: 1) "Starter-kit" packages in which a few "core" modules are purchased with the ability to add additional modules later, and 2) "Trial-basis" or time-share packages which essentially allow companies to rent or lease the software for a specified period of time after which the software may be purchased. While the piecemeal approach can be attractive in that a company can begin to implement a system quickly and with minimal preliminary planning, it is also risky for the same reason. That is, as more functions are added, a company may find itself locked into less flexible functional capability than if more detailed pre-implementation planning had been done. The larger and more complex a user's operations, the more risk inherent in the piecemeal approach.

In order to effect a well designed EDM system, a comprehensive approach involving detailed front-end planning is recommended. The main objective of this approach is the preparation of a detailed conceptual design enabling the automation of various EDM functions to be accomplished in an integrated fashion. These steps may be accomplished by in-house staff or by a consultant working in conjunction with key users. The advantage of using a consultant is that personnel experienced in both current environmental affairs and automation of data management systems can be completely dedicated to the design and implementation of the EDM system. The major steps involved in designing a system are listed below.

- Define desired general capabilities and system boundaries. (See Table 2 for an example of a solid and hazardous waste data management system desired by a large chemical processing firm.)

- Compile samples of gross data base and existing functional relationships

- Analyze sample data and integrate with desired capabilities/boundaries to yield rough layout of conceptual logic.

- Interview users and/or managers responsible for system functional areas to obtain the necessary input required to complete the design

TABLE 2 Information Required for Development of A Conceptual Solid and Hazardous Waste Management Data System

Potential Users of System

- Treatment facilities.
- Storage units.
- Large generating departments.
- Environmental Technical Services.
- Purchasing Department - Surplus Sales Office.

System Capabilities

- Ability to update data or data base easily.
- Ability to sort parameters (e.g., particular chemicals).
- Verification of data.
- Track manifest shipments.
- Track waste handling.
- Identify final waste disposition.
- Ability to take in more than one type of input.
- Inspectable by EPA or DEC according to their regulations.
- Records management considerations (i.e., record retention times).
- Networking capability (i.e., geographic distances up to 15 mi.).
- Maximum 1-week recovery time.
- Hardware that withstands a production environment.
- Vendor supported.

System Output

- Permit compliance reports.
- Automatic tax and fee computation.
- Assist in preparing "Material for Special Disposal" tickets (i.e., internal tracking).
- Provide data for individual state reports.
- Provide data for Company-generated internal reports.

Required/Desired Records To Be Kept

- Inventory and transaction records of all wastes (both hazardous and non-hazardous).
- Cross-reference manifest to disposal date/method.

Other Related Data Systems

- Existing accounting systems (e.g., charge-back system).
- Waste chemical survey data.

- Complete design and draft conceptual design report to include:
  - overall system description
  - functions and processes
  - inputs/outputs
  - data base requirements
  - logic diagrams
  - computer facilities, i.e., processor, storage, peripherals, centralized vs. distributed considerations, available vs. custom software options
  - cost benefit analysis
  - recommendations

- Review, approve and finalize conceptual design report

- Prepare source code, documentation, test specification

- Test and complete debugging

- Conduct user training

This type of detailed, comprehensive approach to the design and implementation of an EDM system requires the dedication of considerable time and resources initially, but as discussed above, this front-end investment can pay big dividends later in terms of options for flexible growth. Failure to develop a well defined automation plan may result in numerous functions being individually computerized but not integrated. Further, a well defined system standard and implementation plan will minimize problems associated with future upgrades to new hardware.

CASE STUDIES

The following case studies will illustrate the approaches taken by two companies to develop an EDM system.

Orange & Rockland Utility (ORU)

ORU is a large Eastern utility headquartered in Pearl River, New York. ORU has a small environmental staff and was interested in automating their environmental affairs. ORU chose to conduct a study prior to deciding whether to actually implement a system. Quadrex Corporation was retained to conduct the scoping study.

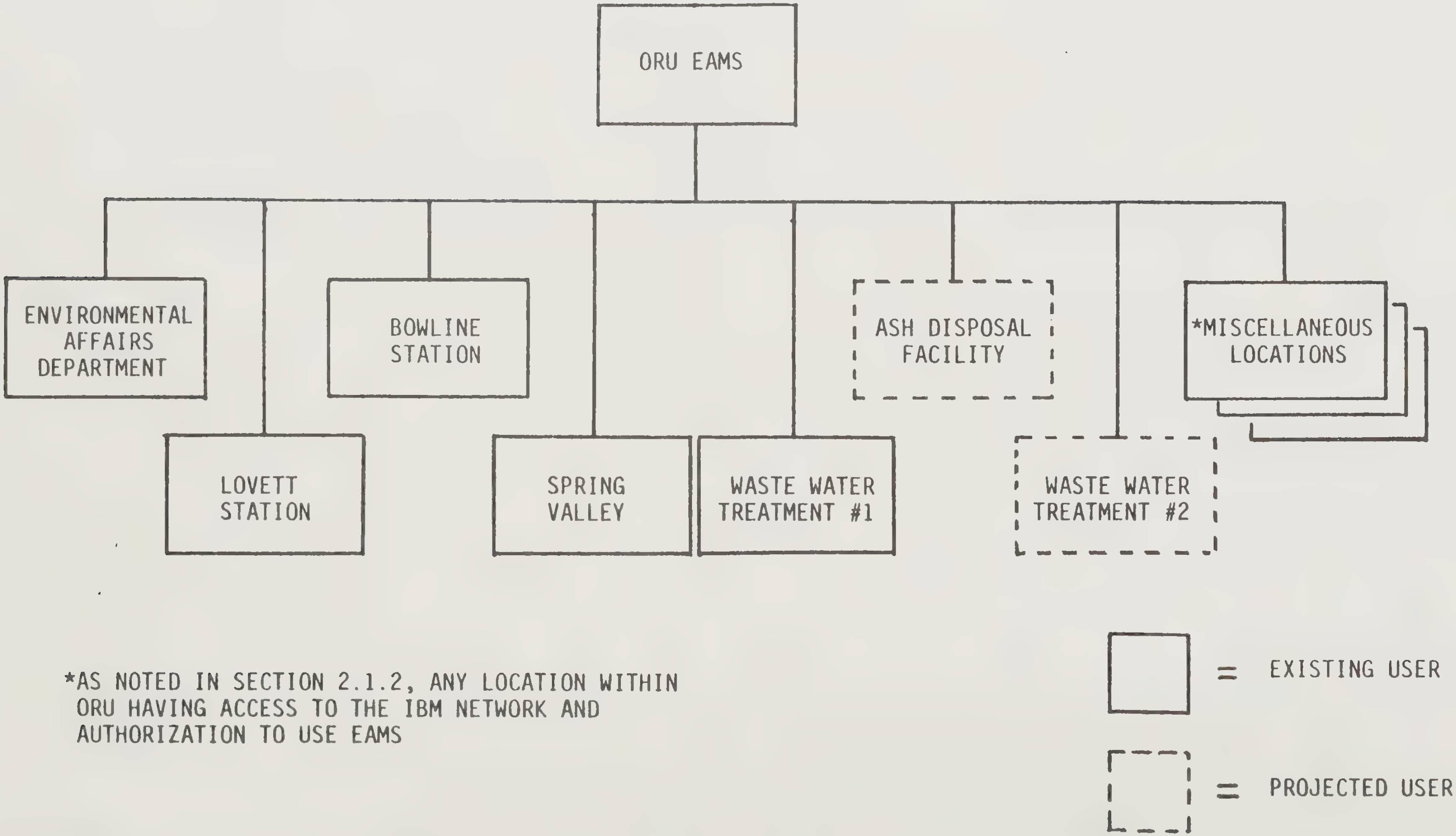
ORU planned to integrate seven locations into an environmental information system. Figure 1 details the system users and Figure 2 details the desired system capabilities. Table 3 details the proposed user access to the system.

The scoping study proceeded as follows:

ORU SCOPING STUDY

	PHASE	ACTIVITY
I.	Preliminary investigation/ identification of information needs	• Quadrex and ORU conducted preliminary discussions to determine ORU's needs • A detailed outline of all data necessary to conduct study was prepared
II.	ORU review	• ORU reviewed the outline • ORU and Quadrex resolved comments • ORU assembled all information necessary to conduct a study
III.	Onsite meetings	• ORU and Quadrex reviewed assembled ORU data • Quadrex conducted detailed discussions with ORU staff to define system implementation requirements

ORU EAMS USER NET



*AS NOTED IN SECTION 2.1.2, ANY LOCATION WITHIN ORU HAVING ACCESS TO THE IBM NETWORK AND AUTHORIZATION TO USE EAMS

Figure 1

ORU EAMS MODULES

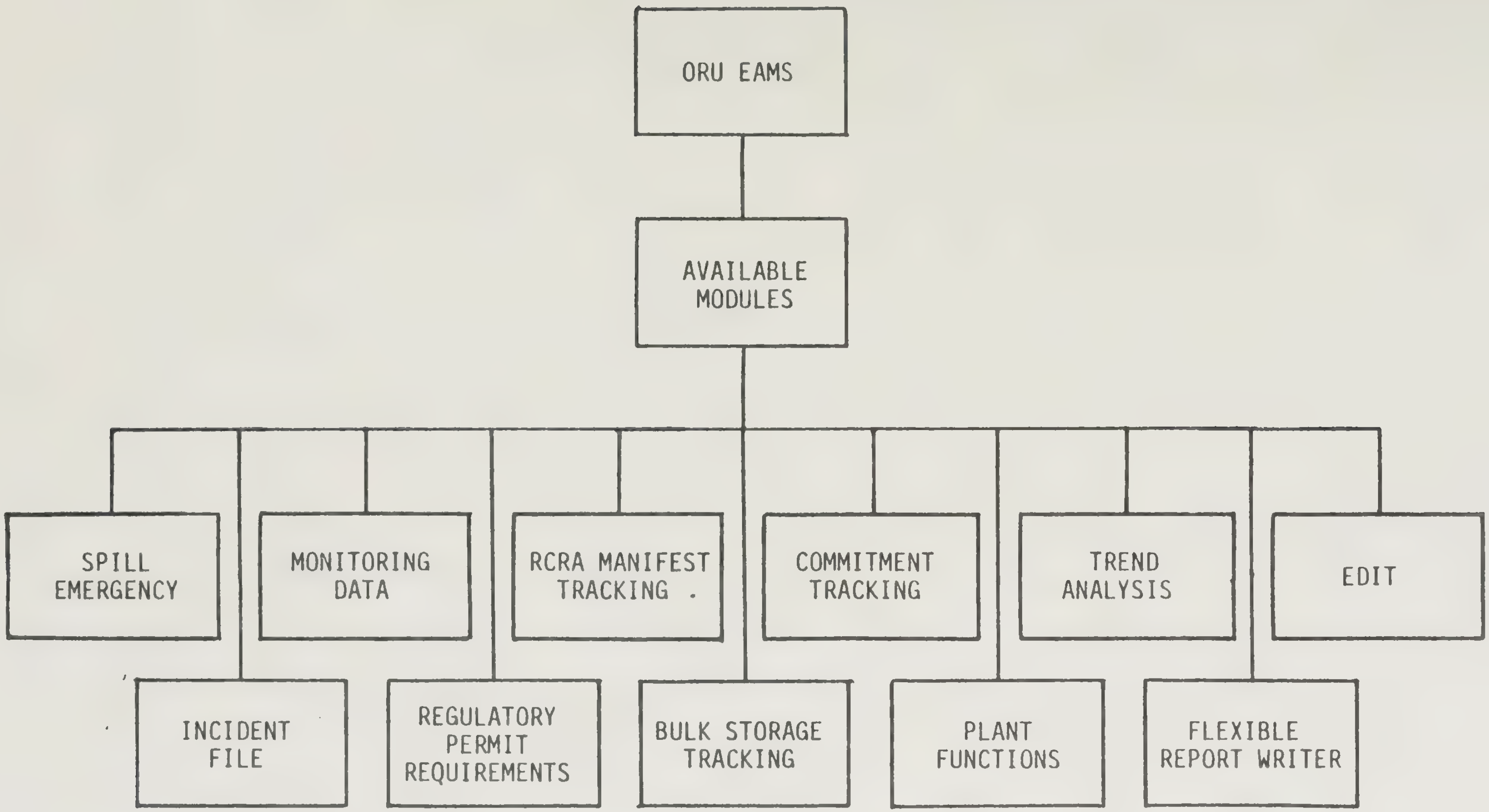


Figure 2

Table 3 EAMS Access Availability

EAMS Facilities	Modules								
	Spill Emergency	Incident# Reporting	Monitoring Data	Regulatory Permit	Commitment Tracking	Plant Function	Trend Analysis	Flexible Report Writer	Edit
Current									
Environmental Affairs Dept.	Y/Y	Y/Y	*/Y	Y/Y	Y/Y	*/Y	*/Y	*/Y	Y/Y
Lovett Station	-/Y	Y/Y	*/Y	-/Y	Y/Y	*/Y	*/Y	*/Y	-/-
Bowline Station	-/Y	Y/Y	*/Y	-/Y	Y/Y	*/Y	*/Y	*/Y	-/-
Spring Valley	-/Y	Y/Y	*/Y	-/Y	Y/Y	*/Y	*/Y	*/Y	-/-
Waste Water 1	-/Y	Y/Y	*/Y	-/Y	Y/Y	*/Y	*/Y	*/Y	-/-
Projected									
Ash Disposal	-/Y	Y/Y	*/Y	-/Y	Y/Y	*/Y	*/Y	*/Y	Y/Y
Waste Water 2	-/Y	Y/Y	*/Y	-/Y	Y/Y	*/Y	*/Y	*/Y	-/-

Key: Ability to enter data/ability to access data.

Y: Yes

-: No Capability

*: Each facility has the ability to enter environmental information pertinent to its reporting responsibilities.

#Note: Automatic incident reporting data will be generated through an access to the Spill Emergency Module and through a noncompliance entry in the Monitoring Data Module.

PHASE	ACTIVITY
IV. Submit final report	• Quadrex consolidated all inputs from onsite meetings • Quadrex finalized study • Quadrex submitted report to ORU which detailed a conceptual EDM system and various development options

Upon completion of the study, ORU conducted an extensive in-house review of their available options. ORU went out for bids approximately one year later and they are currently reviewing vendor proposals to develop an EDM system based on the preliminary design which was established in the scoping study.

This one-year lag from the completion of the scoping study until proposals were requested reflected the long lead-time necessary to budget funds and secure in-house approvals.

Duquesne Light Company (DLC) - Pittsburgh, Pennsylvania

DLC is a large Eastern utility. DLC is headquartered in Pittsburgh, and has offices and plants located throughout western Pennsylvania. DLC's upper management decided that an EDM system would be installed. The DLC environmental staff went on to define the system scope and then request bids from qualified vendors (DLC's data processing staff was unable to develop the system internally due to other commitments). Quadrex was selected to design and develop the DLC system. The purpose and a brief overview of the system's capabilities and implementation approach are described as follows:

General Description of DLC EAIMS

The Environmental Affairs Information Management System (EAIMS) is a DLC computer information system that facilitates the storage, retrieval, analysis, and management of environmental data and open test information.

Purpose -- The purpose of the EAIMS is to aid in environmental awareness, environmental data management and emergency response capability. A separate module is provided within EAIMS to accomplish these purposes. A listing follows:

Emergency Response Capability -- Spill Emergency Module: Provides timely access to information on routine and emergency procedures to deal with spills and other environmental incidents for all types of substances either generically or by specific substances.

Routine Information Handling -- Chemical Handling Module: Provides up-to-date information on chemcal handling, storage, and disposal procedures.

Incident Report Log Module: Provides a method of logging non-compliances or environmental incidents resulting from exceeding regulatory/permit requirements or spills of chemical substances.

Monitoring Data Module: Provides an efficient and effective method of collecting and storing monitoring data for retrieval and analysis.

Regulatory/Permit Requirements Module: Provides a central location for the storage and access of regulations and permits that are of use to facilities/stations throughout DLC.

Data/Information Base -- The information base, utilized by the EAIMS, contains the following: Chemical profiles; Chemical names; Monitoring data noncompliances, chemical spills, or other environmental incidents; Air quality (ambient); Other data types (i.e., IW, NPDES, etc., refer to Monitoring Data Module); Material Safety Data Sheet (MSDS), storage, disposal, and emergency spill procedures.

The data may be accessed through the various EAIMS modules for review by facility, chemical name, or Chemical Abstract Services (CAS) number. Updating capabilities are provided to authorized individuals only at each station. (Note: By "Chemical" name, we mean the scientific or common generic names given to a substance -- i.e., Windex and $NHSO_4$ refer to the same compound.)

User Network -- The EAIMS is linked to 13 facilities/departments within DLC. These 13 facilities comprise the EAIMS user network that follows: Environmental Affairs Department, Beaver Valley Unit 1, Beaver Valley Unit 2, Brunot Island, Chemistry Lab, Cheswick, Elrama, Phillips, Shippingport, Stanwix, Substations and Shops, Transmission and Distribution, Warwick Mine.

The overall EAIMS system operates within the DLC computer system. Use of the EAIMS data/information base is shared by all departments.

Quadrex utilized a 3-phased program to develop and deliver the DLC environmental data management software system. The program outline was as follows:

Phase I — Detailed System Design
- Task 1 -- Design Planning
- Task 2 -- Preparation and Review of Draft Design Specification
- Task 3 -- Preparation and Approval of Final Design Specification

Phase II	Programming	
	Task 4 -- Source Code Preparation	
	Task 5 -- System Acceptance Testing	
Phase III	System Turnover	
	Task 6 -- Documentation	
	Task 7 -- Training	

The tasks associated with each phase are described in detail below.

Phase I Detailed System Design

Task 1 -- Design Planning

Representative samples of all documentation to be included on the DLC system was assembled. Complete documentation included one blank and one filled-out sample of all environmental and plant function data forms and logs, spill procedures, leak procedures, environmental and plant function data calculation procedures, and any administrative data handling procedures currently in effect. A detailed review of all documentation was conducted and a listing of all issues and questions regarding the application of the documents in the system was developed. Meetings were held to review this information and to finalize design plans. The proposed system functional description was then reviewed to insure there was mutual understanding and concurrence. System functions, capabilities and conceptual logic which required further definition were identified and sufficiently clarified for detailed design purposes. All environmental documentation forms, logs, text formats, calculation procedures, and associated issues were reviewed to ensure the purpose and function of each category of information to be included in the data base was clearly understood. Future plans for additional system capabilities were also discussed.

The results of all meetings were documented, and together with the proposal, this documentation formed the basis for preparation of the draft system design specification.

Task 2 -- Preparation and Review of Draft Design Specification

Upon completion of the design planning meetings, the draft design specification was prepared. The draft design specification included the following:

- detailed logic diagrams showing branches and levels within each module
- screen layouts
- file descriptions
- data base descriptions
- access requirements
- detailed description of all module transactions

Upon completion of the draft design specification, copies were submitted to DLC for review for conformance with the design bases established in Task 1. All DLC review comments and concerns were documented and forwarded to Quadrex.

Task 3 -- Preparation and Approval of Final Design Specification

All DLC comments were resolved and incorporated into a final design specification. Quadrex personnel returned to DLC offices to fine-tune the system design. Upon resolution and incorporation of all comments, all resolution actions were documented and returned to DLC with a copy of the final design specification for approval. Upon completion of minor editorial corrections, the design specification was approved by both DLC and Quadrex. Software coding in accordance with this agreed-upon specification then began.

Phase II System Programming Implementation

Task 4 -- Source Code Preparation

Preparation of the DLC-specific source code was performed on DLC's computer system to optimize cost effectiveness.

When the software development was completed, the code was loaded on DLC's computer.

The system source was menu driven with simple non-procedural statements. Standard audit and security systems conformed to DLC standards. The system emphasized a user-oriented system to ensure an interactive dialogue between the user and the terminal.

The screen formats for input and output included consistent user log-in procedures, menus, levels of security, prompts, screen print function, forms, and program function keys to aid in simplifying system user interface. The program included edits for data and prompts for providing responses stating clear explanations regarding error(s) encountered. Valid data is required before allowing any record creation or update. The program was written in COBOL/CICS command level. The program provided functions to perform adds, deletes, and changes to the appropriate files. The environmental affairs management system provided an interactive report select-procedure to interface with the user through the use of menus and prompting to produce the hard copy reports requested.

Task 5 -- System Acceptance Testing

When all source code preparation was completed, sufficient DLC data was loaded to demonstrate the proper functioning of all transactions in accordance with the design specification.

Phase III System Turnover

Task 6 -- Documentation

The programmers manual and the users manual were prepared in conjunction with the programming process. Upon completion of system acceptance testing, the programmer's and user's manuals were finalized.

Task 7 -- Training

Upon completion of the final programmer's and user's manuals, training was conducted for users and programmers. Separate sessions were conducted for the general users and the programmers, and an executive summary briefing was conducted for management personnel.

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EMERGENCY RESPONSE

HAZMAT RESPONSE CASE STUDY

by

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O.H. Materials is an environmental services contractor specializing in on-site treatment of hazardous materials. The company began in Ohio in 1969 and currently employs approximately 600 people - of which 150 are chemists, engineers, biologists, and hydrogeologists. To date, we have completed over 3000 jobs in over 40 states and several providences in Canada. Our corporate office is located in Findlay, Ohio, and we have 12 regional response centers throughout the U.S. The company got its start in the emergency response business and has successfully worked with thousands of different hazardous and toxic substances. The following presentation will chronicle one of O.H. Materials emergency response case studies.

In January of 1978, our 24-hour dispatch center was contacted by a major railroad company. One of their trains had been involved in a serious derailment near a small town in Northern Kentucky. Utilizing one of O.H. Materials three corporate airplanes, we flew an investigating team to the scene of the accident. The crew consisted of a field chemist, the head of our transfer crew, and a site supervisor all equipped with the necessary protective clothing and sampling equipment. Our response time was approximately three hours from the time we were called by the railroad to the time our crew arrived on the scene.

Upon arriving at the job site, we determined that several rail cars of coke and 4 - 20,000 gal. tanks cars of acrylonitrile were involved in the derailment. Acrylonitrile has a very low flash point and is an extremely flammable liquid. It also is currently listed on the EPA list of priority pollutants. Some of the cars of acrylonitrile had ruptured and were burning with a very intense heat and smoke. The fumes from burning acrylonitrile are also very toxic. The fire from the burning acrylonitrile had also caused the coke to catch on fire. This material burns with a very intense heat, and the outer wall of the rail car was melted away and only the structural framework of the car was intact.

With a fire of this magnitude, and involving a hazardous material such as acrylonitrile, often more damage can be done trying to extinguish the fire. Adding water to a fire of this type spreads the contaminants over a much larger area and creates an additional problem with treatment and disposal of the large volumes of contaminated water. Therefore, in this incident, the fire was allowed to continue burning for approximately 36 hours until it was self extinguished by a lack of available oxygen and the majority of acrylonitrile had been consumed. This is one of the more critical parts of the clean-up, since potential always exists for re-ignition of the flammable product.

Some of the burning product ran into a nearby creek setting it on fire and contaminating the creek bed for a distance of approximately 200 feet. As the burning product entered a nearby river, the flame was extinguished causing raw product to enter the river.

Approximately three miles down river from the accident scene, the inlet pipe for the town's drinking water supply was located. The Kentucky Department of Natural Resources took immediate action and ordered the drinking water inlet line closed and began intensive air monitoring downwind to determine if evacuation was required.

During the initial period while the fire was permitted to burn itself out, the O.H. Materials team met with railroad representatives and a technical team from the manufacturer of the product to determine the next course of action. Our efforts at this point were to identify and trace the potential paths of contamination and to assess the resources needed to begin the clean-up. Using a skid mounted vacuum recovery unit, technicians began preparation to recover pockets of raw product and contaminated water. One of our mini-transfer trailers was set up to begin transferring the remaining acrylonitrile from the damaged rail cars to additional tankers supplied by the railroad. Approximately 10,000 gallons of virgin acrylonitrile were transferred and sent back to the manufacturer for re-processing.

A sixteen foot vertical type carbon filter system containing 16,000 pounds of activated carbon was brought in on the project within 24 hours after we were notified on the accident. This filter system would be used to treat run-off water from the site in case of rain, in order to minimize or eliminate contaminants going to the nearby river.

The ambient temperature at this location when the accident occurred went from 40 degrees down to as low as 10 degrees Fahrenheit requiring the use of heat tape and insulation on the carbon filter to prevent freezing and facilitate its reliable operation.

Approximately two days after the initial accident, the railroad's contractor had completed removal of debris, completed re-grading of the roadbed, and began laying down 50 foot track panels - this was an intense effort all designed to get the rail line back into service as soon as possible.

The area of contamination extended along the track for a distance of approximately 200 yards in length, width at places being approximately 20 yards. The depth of contamination was typically 0-8 feet below the surface with some areas of contamination going as deep as 15 feet. The concentration varied anywhere from a few ppm to in excess of 40,000 ppm.

Prior to O.H. Materials development of its underground recovery and treatment system, a spill clean-up of this type would consist of evacuation of all contaminated soil and removal to a licensed disposal facility. It was estimated that to remediate this spill using the excavation method

would require removal of approximately 200-400 rail cars of contaminated soil. Excavation, transportation, disposal and decontamination of rail cars for this project were estimated at a cost of 3-5 million dollars.

In addition to these costs, the railroad line would be out of service for approximately 4-6 weeks resulting in lost revenue to the railroad well in excess of $1,000,000.

Approximately two weeks after the incident, initial soil sample analyses were completed and reviewed. O.H. Materials representatives and personnel from the railroad company met with officials from the Kentucky DNR to discuss the status of the clean-up. O.H. Materials was then asked by its client to propose a more cost-effective and more environmentally sound method of remediation than the traditional excavation and disposal of all contaminated soil. O.H. Materials proposed the implementation of its unique underground recovery and treatment system. The system involves the installation of a series of recovery wells in the area of contaminated soil.

In addition to our underground recovery and treatment system, an interceptor trench was installed at a strategic location at the site to intercept and collect any contaminated run-off water. Contaminated water was pneumatically pumped from the recovery wells. This water is first sent to a contaminated water storage area. From there, the water is pumped to the primary treatment system consisting of a clarifier and/or sand filters. This process removes suspended materials which helps to prevent blinding of the carbon cells. From there the water is sent to the carbon filters where the majority of the acrylonitrile is removed. The water is then sent to aeration and holding ponds for final analysis.

In this case, we were permitted to aerate the water containing small traces of acrylonitrile as long as we didn't exceed the TLV for this product in air. For this product, the TLV (Threshold Limit Value) was 2 ppm.

The aeration ponds also serve as holding basins for treated water since all water must be analyzed and certified to meet discharge requirements prior to its release to the stream. Water which is pumped into the injection wells, passes through the contaminated soil and carries with it some of the acrylonitrile. This contaminated water is removed via the recovery wells and is sent to the above ground treatment system.

The acrylonitrile was removed using both activated carbon and aeration, and the clean water reinjected into the contaminated soil. This process continues until the level of contaminants in the soil falls below the clean-up criteria established by the regulatory agencies.

In this case, our clean-up criteria were set so that any water containing acrylonitrile was less than 100 ppb in concentration. The entire site was surrounded by a containment dike in order to collect any contaminated run-off water. Also, we constructed a diversionary dike up gradient of the site in order to collect and divert any clean run-off directly to the adjoining creek.

A complete set of injection wells and recovery wells was set up along the contaminated road bed. The well points are joined by a six inch header system. The system is designed to permit reversing flow if necessary. Also, as the clean-up progresses, the injection wells can be moved closer to the recovery wells to facilitate a more rapid clean-up time. This is typical of the vacuum system used for the recovery wells.

A containment dike around the entire perimeter of the site eases collection of contaminated puddles of water via vacuum trucks for treatment on site. The soil in this area was a clay material having a very low permeability and, therefore, rapid migration of contaminated water off site was a not a problem.

"Second generation" type of portable aeration ponds or holding basins are made by bolting together specially designed aluminum panels and lined with a material resistant to the chemicals involved. These units can be easily assembled on site to a size anywhere from 10,000 gallons to 50,000 gallon capacity. The temporary building housed the discharge basin along with the carbon filters used for the removal of acrylonitrile from contaminated water. These filters are skid mounted, portable, and fabricated in O.H. Materials' fabrication shop.

Water samples were continually obtained and analyzed from the well points, monitoring wells, before and after the sand filters, after the carbon filters, and before discharge and/or reprocessing of treated water. When the project was first started, the railroad company was using the services of a contract laboratory for analytical work. This involved considerable expense since the samples had to be flown by chartered aircraft to a laboratory which was a distance of several hundred miles from the job site. It was at this point that O.H. Materials brought their mobile lab onto the job site in order to reduce sample turn-around time and reduce teh overall costs of the analytical program. The mobile lab was equipped with a gas chromatograph and related integrator for detection of low levels of acrylonitrile.

Automatic devices were used to sample monitoring wells and also to continually monitor air quality for detectable levels of hazardous organic vapors. An on site supervisor continually monitored the progress of the project, and provided interface between O.H. Materials and the concerned regulatory agencies and provided strict accounting of all costs for client approval.

Our fixed facility laboratory provided gas chromatograph/mass spec. capabilities to provide quality assurance and quality control for our mobile laboratories.

After several months into the project, a pilot study was begun to determine if biological degradation was a feasible adjunct to carbon filtration. The advantages of biological degradation are that it totally destroys the hazardous material, minimizes or eliminates off-site disposal and the potential long-term liability that goes with it, and can often be more cost effective.

When the recovery wells began to show acrylonitrile levels of approximately 1200 ppm, we started our biological degradation evaluation. Our tests indicated that this concentration was too high to permit biological activity. Subsequent tests at lower levels of acrylonitrile indicated that at a level somewhere below 1000 ppm, biological treatment of the acrylonitrile was feasible. Using the appropriate strains of bacteria, and the proper nutrients, stock solutions of the bacteria were prepared and injected into the system. As we moved the injection system throughout the spill area to flush the soil, high concentrations of acrylonitrile were broken loose.

To summarize, this project in Kentucky was completed in seven months at a cost of about one third the estimated cost for excavation. In addition to these cost savings, by utilizing the O.H. Materials underground recovery and treatment system, the railroad company was able to continue operating the rail line uninterrupted during the entire clean-up project.

For approximately one year after the completion of clean-up, periodic analyses were performed to confirm that clean-up goals had been achieved.

Since this project, we have successfully completed a number of jobs utilizing biological degradation of various types of hazardous organic substances - including isopropanol, acetone, crude oil sludges, petroleum hydrocarbons, n-butylacrylate, methylene chloride, ethylene glycol, and various types of phenolic compounds. An electrolytic respirometer is one method we use to determine if a particular organic material or a mixture of organic substances can be successfully biologically treated.

Some examples of successful jobs utilizing biological degradation:

- Clean-up of a 30,000 gallon spill of chloroform. The treatment process involved sand filtration, a heated volatile organic sparging unit, portable clarifier, carbon filtration and aeration. (Although this appears to be a rather elaborate treatment system, the cost of clean-up for this project was significantly lower than for traditional treatment methods.)

- Clean-up of 100,000 gallons of a mixture of five different organic compounds as a result of a train derailment. The project involved both surface and sub-surface clean-up.

- Clean-up of a tank car of styrene monomer at a major railroad yard. The treatment process involved carbon filtration and biological degradation. In addition, portable air strippers were also utilized to facilitate clean-up. Since this project several years ago, we have completed literally hundreds of similar projects involving a wide variety of contaminants.

EMERGENCY RESPONSE TO GROUNDWATER SPILLS

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Initially, lets define an emergency. It could be:

1. The receipt of certified mail from a regulatory agency requesting immediate remedial action at a site for which you are responsible.

2. Petroleum odors rising from the foundation of your building, and there is a gasoline station nearby.

3. Sudden knowledge of the results of a laboratory analysis of a groundwater sample from property you recently purchased.

4. As the owner of a gasoline/service station, the morning "sticking"of an underground storage tank, indicates that there has been a loss of 5,000 gallons of leaded fuel.

There are many others, but lets select number four as our case study. To make the scenario broader in its scope, I've combined three actual case studies (one each in Santa Clara County, Los Angeles County, and Orange County, California).

The first responsibility is to notify the Fire Department or the RWQCB or Health Services or another regulatory agency depending on the location of the spill.

Next, develop a workplan and review with your client and the lead agency prior to initiating any action at the site:

Determining the contaminent plume is the initial objective. Things we know regarding this are:

1. The plume will have defined boundaries.

2. The contaminent will float on water or sink depending on the density.

3. Contamination will move in the direction of the hydraulic gradient.

4. If not blocked or immobilized, the contaminents will reach rivers, streams, water production wells, springs, etc.

Recovery concepts and options are:

1. Interceptor trenches

2. Recovery wells

3. Evacuation of soils or liquids

4. Blockage of the plume

5. Neutralize or immobilize the contaminents

Most frequently, wells are drilled using a hollow stem auger with a split spoon sampler.

1. Observation wells are drilled for viewing, "sniffing" and sampling of soils to determine the plume of contamination.

2. Often observation wells are converted to monitoring wells by installing P.V.C. pipe in sand gravel and concrete.

3. For valid water samples, monitoring wells are developed by our purging or manually bailing the liquids. Approximately 3-5 times the volume of the well should be removed and the well allowed to recharge prior to sampling.

4. A 4" completed well can be converted to a recovery well if necessary. Of course a 12" or 24" well is more desirable for major recovery of a product.

5. Borings must be logged by a geologist and along with well locations and well construction placed in the project report to the lead regulatory agency.

Using a field photoionization meter for "sniffing" soils is a valuable part of the investigation as long as the readings are properly interpreted. Our meters are usually calibrated to benzene, but the PPM's indicated are correct only if there are no background or interfering constituents.

Also, field meter readings may differ from chemical laboratory analyses due to the technique and care used in placing samples in the containers. Voids or spaces as well as insufficient refrigeration allow vapors to escape from the soils prior to lab analysis. At the laboratory end, improper testing procedures or not adhering to proper testing procedures can result in inaccurate analysis.

Soils removal requirements at gasoline stations are usually on a case by case basis, ranging from non-detectable, to 10 PPM to a significantly higher concentration of total hydrocarbons. Trucks must be lined with plastic prior to loading and transporting hazardous material to a disposal site and the truck must be permitted for such service. Remember the generator usually owns the disposed hazardous material forever, so the

selection of the disposal site and the correct completion and distribution of a hazardous waste manifest is essential.

Considerable disposal cost savings are possible by knowing the wastes that are acceptable by a Class II-1 disposal site since the fees and taxes are frequently less than one-half the amount charged by a Class I site.

Some of the requirements for removing hazardous material underground storage tanks are:

1. Remove remaining product by vacuum truck or other pumping system, flush tank and remove rinse water.

2. Introduce dry ice into tank to drive out vapors.

3. Reduce lower explosive level to less than 20% before removing and transporting tank to disposal site.

4. Take 2 or more soil samples from directly beneath the tanks after removal and have analyzed for total hydrocarbons and/or total lead and/or benzene toluene and xylene and/or flashpoint.

Considerations in selecting recovery equipment are:

1. Type of product

2. Groundwater flow conditions and subsurface permeabilities

3. Depth of product

4. Diameter of recovery wells

Contaminated water disposal requirements problems and options are:

1. Discharging of water to storm sewers in a water spreading area may require treatment with carbon adsorption to less than 1 PPB of benzene.

2. Removal of product by vacuum truck and transportation to an approved Class I, II-1 or oil and water separator.

3. Treatments to an approved level and discharge to a sanitary sewage system.

Should any of the readers have questions or comments regarding this paper please call me at (213) 491-4750.

SANTA BARBARA ACID SPILL

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The Santa Barbara acid spill incident is noteworthy for several reasons, including the location of the incident (nearly in the heart of Santa Barbara adjacent to a major drainage channel) and the nature and visibility of the incident. These features combined to yield a response and cleanup effort that incorporated the joint contribution of various emergency response agencies and tested each agency's ability to deal with ramifications, including evacuation, attendant to a major spill incident. Hence, it is worthwhile to review the events following the initial release of Nitric Acid, Sulfuric Acid, Copper Sulfate, Flourboric Acid, and Lead discharged into the Mission Creek Channel the afternoon of May 14, 1984 with the intent that an approach and awareness may be stimulated which could help prevent future incidents, should they occur, and minimize the effects of such incidents on the public and the environment.

There is little doubt concerning the source of the subject spill, however, due to pending litigation associated with the spill it is inappropriate to address the specific cause, events, or persons contributing directly to the incident. It is sufficient for purposes of this account, however, to speculate that incompatible acids reacted inside a vacuum truck to produce, among, other things, a large acid-laden, breathtaking, eye watering, reddish cloud. Many citizens of Santa Barbara were treated at local hospitals for skin, eye and throat irritation resulting from contact with the acid cloud. Generally, the acid cloud provided a visible signal to observers that the event was not yet under control and marked the beginning of Positive Incident Control's involvement with City, County, and State agencies, as well as private contractors and suppliers, in mitigating the incident.

On Monday, May 14, 1984 at approximately 12:40 p.m. the Santa Barbara regional office of Caltrans was notified by the California Highway Patrol of a chemical spill on the northbound land of Highway 101, 100' north of the Carrillo St. on ramp. The northbound lane was immediately thereafter closed by the California Highway Patrol, and Caltrans proceeded to maintain the closure. At 12:57 p.m. Santa Barbara Police Department and Fire Department personnel began evacuating a section of Carrillo St. near the spill incident.

According to the driver of the vacuum truck involved in the incident, fumes escaping the container resulted from a leak in a hose leading from the container to the pump. Ten minutes prior to this, the same driver had speculated the fumes were venting through a vent pipe. Regardless of the source, the driver recommended to the on scene battalion chief to add water to the contents of the container; the driver maintained this would solve the problem. The Santa Barbara City Fire Department battalion chief on

scene was correctly unmoved by the truck driver's recommendation. At 1:32 p.m. two (2) firemen were suited in Level I protective gear and sent in to inspect the vacuum truck. Twenty minutes later the truck began to vent even more reddish gas and the evacuation was broadened in scope.

At 2:00 p.m. a six (6) inch valve located in the rear of the vacuum container failed allowing approximately 3,200 gallons of material to spill from the container onto the shoulder of the highway. Reddish gas fumed into the air as the fluid contents of the truck flowed down the shoulder of the roadway, and subsequently, into a drainage inlet. Minutes later the fluids discharged into the Mission Creek Channel and continued fuming down the channel toward the ocean. Caltrans employees and City of Santa Barbara employees worked feverishly to dam the Mission Creek Channel immediately below the Cannon Perdido Bridge. At approximately 3:30 p.m., the channel was successfully diked. Fortunately, the entire spill was contained at the Cannon Perdido Bridge.

Positive Incident Control (P.I.C., the private company responsible for the subsequent cleanup) emergency response personnel were placed on standby alert by Caltrans at 2:00 p.m. At 3:06 p.m., P.I.C. dispatched emergency response personnel from its Bakersfield office. At 4:08 p.m., P.I.C.'s emergency response team arrived at the scene of the spill incident. At this time, the reddish acid cloud remained visible from the scene as it slowly drifted over portions of Santa Barbara. Firemen, operating from a hook and ladder truck, provided a water mist over the vacuum truck in an effort to reduce gases emitting from the container. News media, Police Department, Health Department, Public Works, Flood Control, Caltrans, and Fish and Game personnel, along with myriads of other public and private observers, were on scene to witness an event obviously not yet under control.

P.I.C., with the benefit of a briefing from fire personnel, proceeded to acquire a sample of the contents of the vacuum container. On-scene analysis of the sample indicated the presence of Nitric and Sulfuric Acid. Accordingly, at approximately 5:00 p.m. P.I.C. personnel opened the dome of the vacuum container and injected soda ash mixed with water to neutralize the remaining contents of the vessel. The neutralized material was then transferred to a stainless steel vacuum truck and manifested for disposal.

Decontamination and cleanup of the channel was complicated by volumes of water discharged upstream from the incident and by the extremely high water table present in the area of the spill. Regardless of such problems, approximately 300,000 gallons of contaminated fluids were removed from the channel and hauled to the Casmalia Class I disposal site. In addition to such contaminated fluids, approximately 1,000 c.y. of contaminated solids were removed from the channel bed under the Cannon Perdido Bridge. Removal of solids was necessary, not because of acids present in the spilled material, but because of the presence of copper sulfate in the material (copper can be hazardous to marine life).

While Positive Incident Control was confronted with many challenges attendant to the cleanup, by far the most serious challenge emanating from

the incident was getting paid for cleanup work performed. Caltrans promptly paid approximately $80,000.00 for all work performed on the Caltrans right-away. However, the preponderance of cleanup work performed by P.I.C. was performed in a bureaucratic "no-man's-land" off the Caltrans right-away.

Due to insufficient reporting by public officials, funds normally available through the Department of Health Services were simply unavailable. No expedient mechanism for payment could be found. P.I.C., its subcontractors, and its suppliers remained unpaid for several agonizing months. Only through the determined efforts of the California Department of Fish and Game and Assemblyman Don Rodgers was payment finally made. The California Department of Fish and Game now awaits the passage of Assemblyman Don Rodgers' AB 444 which is intended to provide an emergency appropriation from the legislature earmarked to reimburse the Department of Fish and Game for courageously doing what was necessary to preserve the credibility of the State of California's hazardous material cleanup program.

DESIGN OF EMERGENCY RESPONSE UNITS

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A hazardous material emergency response unit must be tailored to satisfy the needs of the facility or community it will serve. There is no "perfect" design to satisfy all requirements.

The primary consideration when designing an emergency response unit is its size. The size of the unit should be established after surveying the access routes and distances to expected incident locations and after determining the equipment needed at potential hazardous material incidents in the area served.

If the area served is a small or compact facility, some absorbents and clean-up equipment in storage cabinets at key locations and/or a small push cart might be appropriate. On the other hand, if the response area is large, a large emergency response unit equipped with many resources would be required.

The role of the team using the emergency response unit must be determined prior to designing the unit. Will the team be performing only scene management and stabilization operations, or will they be doing clean-up and scene restoration as well. If the role of the team is limited, the equipment required on the emergency response unit will be substantially less than the equipment required for a team and emergency response unit whose function includes total mitigation activities.

Once the role of the team and emergency response unit has been determined, it is necessary to perform a needs assessment of equipment. This is accomplished in a couple of ways. First, research the hazardous materials incidents that have occurred in the area served. Talk with the people who responded to those incidents and compile a list of the equipment they used and equipment that could have been used to terminate the incident more easily and effectively.

Secondly, survey the area served and determine the potential for incidents. From this, an equipment and supplies list can be developed.

Equipment for hazardous materials emergency response units falls into six general categories: (1) identification and hazard assessment materials, such as binoculars, hazcat kits, and reference materials; (2) protective equipment, such as clothing, respiratory protection, and first-aid supplies; (3) tools, both hand and mechanical; (4) environmental monitoring instruments, such as combustibility detectors, oxygen meters, and colorimetric tubes; (5) control devices for leak stopping and containment, such as plugs, putty, tape, inflatable devices, absorbents, shovels, and salvage drums; and (6) scene restoration equipment for clean-up and decontamination of equipment, supplies, and the environment.

When your list is complete, and the tools, supplies, and equipment for the vehicle are identified, the size of the vehicle can be determined. For some lists, a semi-truck and trailer might be needed, but due to budget constraints and pressure from management, something with only two or three axles may have to suffice. For facilities with limited space, push carts and storage areas strategically situated thoughout the facility may be the way to go.

Whatever design is determined, the real world now becomes a reality and compromise is often the result. Your facility or motor pool should be surveyed for an appropriate response unit for conversion. This unit should have the capability of modification to accomplish the tasks you have determined necessary. It has to be large enough to accommodate the equipment needed, yet small enough to travel through its service area. Remember to allow room for expansion.

If no unit is available internally, one must be purchased. There are companies that have hazardous materials response units ready for delivery, varying in size from the small push cart to large specialized vehicles or trailers. Many companies will build an emergency response unit to your specifications. All it takes is lots of money.

The in-service response units are as different internally as the individuals who designed them, but several exterior similarities exist. Many fire departments have chosen the step van for their response unit. This style is readily available, reasonably priced, and easily modified for compartments, shelves, etc. Some fire departments have

their hazardous materials emergency response units performing more than one function, such as truck company operations, lighting, high rise rescue, air supply, rescue, or communications. Several fire departments operate their hazardous materials team in conjunction with a squad due to manning and equipment limitations.

Due to the on-site availability of resources for industrial hazardous materials teams, size of response area and access routes, and complete knowledge of the hazards through pre-planning and inventory control records, most industrial emergency response units are smaller than their public counterparts. These industrial emergency response units are often battery powered carts, although some companies have chosen to utilize trailers that can be pulled to the incident by security vehicles, fork-lifts, etc.

The commercial clean-up contractors have used several types of vehicles including: step vans, cargo vans, stake beds, and trucks that can leave a "drop box" full of equipment and supplies at the scene.

There are several important advantages to trailers and drop boxes, both for industry and the fire service. The units can be locked and stored for indefinite periods without concern for dead batteries, oil changes, etc. When joint powers or mutual aid agreements for hazardous materials incidents exist, the trailer may be the most appropriate emergency response unit.

Since many emergency response units for hazardous materials incidents may not be used daily, for security purposes consideration should be given to enclosed compartments capable of being locked and possibly even sealed. Large lift-up doors have been used effectively on smaller units, and these doors double as a shelter from the weather when in the open position.

It is important to make protective equipment easily accessible. Safety equipment such as breathing apparatus, eyewashes, and first-aid supplies should be readily accessible. Absorbents and other "dirty" items would be best kept outside or away from instruments and protective equipment. Any closed compartments or containers should be marked with the contents. If possible, open screen type doors should be used on the interior compartments so personnel can see the contents.

There are advantages and disadvantages to every design, what is appropriate for one department or facility may not

be appropriate for another. What works for you, may not work for the department or facility next door due to job functions, management cooperation, resources, etc. Consider your objectives when designing your emergency response unit. Identify your potential hazardous materials problems, understand fully the role your team will play in a hazardous materials emergency, determine the materials and equipment necessary to accomplish your objectives, and design an emergency response unit that will work for you. Good luck!

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The following list is not intended to be a complete and non-negotiable inventory for chemical response teams. These items, of personal protection, should be viewed as suggested equipment for a basic hazardous material van. The inventory should vary as to the number of technicians responding, the scope of the area covered and the degree of involvement in the actual emergency. If your only duty is to remove injured workers and secure the area your needs would be different than someone who is going to clean up and dispose hazardous material.

Prior to entry into a hazardous area one should understand as much as possible about the situation they are about to encounter. This knowledge is best gained through printed material such as a bill of lading or a material safety data sheet. If these items are not available instrumentation is the next best bet. The following list suggests some popular items:

1. Combustible gas/02 deficiency meter w/pump
2. Draeger hand pump w/3 meter hose and tubes
3. Air current or wind direction monitor
4. Carbon monoxide monitor with alarm
5. Infared heat scanner
6. Radiation detection kit
7. P. H. paper

These instruments should be tended by a qualified safety or indistrial hygenist. There is no substitute for a well trained individual at an emergency site.

Probably the most important item to select for a spill emergency is the protective suit. There are four E. P. A. classifications of suits:

Class A Totally encapsulated suit, self contained breathing equipment mandatory. Air bottle may be inside or outside of suit.

Class B Impervious suit selected for particular hazard. Maybe one or two piece. Respiratory options are self contained or airline respirator.

Class C Imprevious suit selected for specific hazard. Some suggestions, neoprene, P. V. C. coated tyvek. Suits maybe one or two piece. Mechanical type respirators, goggles and gloves acceptable.

Class D Normal work clothes with gloves and goggles.

The selection of breathing equipment should be dictated by the type of emergency and the extent of training the wearer has been exposed to. Protection factor and duration of breathing time are important factors. There are various types of respirators available. Have a trained professional select the proper type for your emergency.

1. Re-breather oxygen type mask, four hour duration.
2. Self contained breathing air type, 30,40 or 60 minute duration positive pressure mask.
3. Hose line respiratory, full or half mask, air line connected to compressor or air bottle.
   Not positive pressure, should not be used in I.D.L.H. atmosphere.
4. Mechanical cartridge type. Cartridge must be property selected for the atmosphere and the concentrations must be slight. Mask fit is very important.

Other items that should be taken into consideration for personnal protection are:

1. Gloves - these should be selected for each individual occasion as there is no single glove for all applications.

2. Goggles - there are several good brands of goggles on the market today. Suggested ones are non-vented with fogless lens.

3. Boots - these are broken into two main divisions, neoprene or P.V.C. Steel toes are recommended as are steel inner soles.

4. Hard Hats - Brackets & Visors - these items should be worn as a unit and should be compatible

SUGGESTED LIST FOR HAZ/MAT INVENTORY

30 or 60 minute self contained breathing apparatus

Spare bottles for above, at least one per unit

Class A totally encapsulated suit

Class B chemical protection suit

Class C imprevious suit (disposable)

Goggles, chemical splash, fogless lens

Gloves:

- neoprene
- P. V. C.
- nitril butyl rubber
- butyl
- natural rubber
- viton
- 10kv linemans gloves
- linemans cover glove

Hard hat

Bracket

Visor

Large first aid kit

Portable eye wash

Safety harness class 3 parachute type

Boots P. V. C. and neoprene

Airline respiratory w/50' hose sections (optional)

Dust respirators (disposable)

DETECTION EQUIPMENT

Monitor for combustible gas/oxygen deficiency
Gastech Model 1314

Multi-gas detector/extension hose and tubes
Draeger CH304 D

Air current kit
Draeger CH216

Heat scanner

PH hydrion 0-14 ph paper

CD radiation detection kit

TOOLS AND EQUIPMENT
all non-sparking tools

Ball peen hammer 1½ pound

Engineers hammer double face

Mallet 4 pound

Pliers, grove joint

Slotted screwdrivers

Phillips screwdriver

Non-sparking tools (beryllium copper material)

- Sledge hammer 32" 5 pound
- Prybar 36"
- Shovel, square point long handle
- Wrench, pipe various lenghts
- Wrench, adjustable various lengths
- Wrenchs, bung

MISCELLANEOUS TOOLS

Grounding wire assemblies

Gas and water key steel 2"

Pike pole, fiberglass

Jumper cables 16' 400 amp

Funnels, heavy duty polyethylene

Buckets, disposable

Squeegie, 18" with handle

Inflatable pool 15" x 6'

Duct tape 60' by 2" wide

Barricade tape 3" x 1000' marked "HAZARD MATERIALS DO NOT ENTER"

Ice chest 10 gallon capacity

Fire extinguishers various sizes and types

Drum truck 400 lb capacity welded aluminum frame

Clean room vacuum cleaner (Nilfish)

12 gallon recovery drum

55 gallon recovery drum

85 gallon recovery drum

Drum lifting and transfer tool

Drum and tank patching kit

Absorbent pads and booms (various types)

Plug 'N Dike patching material

Salvage tarps, polypropalene

Plastic sheeting, visqueen

Highway type push broom

Hacksaw

Bold cutters

Aluminum ladder

MISCELLANEOUS EQUIPMENT

Reflective triangles

Megaphone super hailer

Camera w/case poloroid/35mm

Calculator

Tape recorder

Freon air horn-hand held

Signs, various warning

Safety laterns, explosion proof

Flashlights, explosion proof

Binoculars

Traffic cones

Inspection mirror

Radios and other communications systems

Polypropalene rope aprox. 200'

The following compatibility charts are furnished by manufactures and are to be used for reference only.

Material swatches are available for sample testing of specific products.

CHEMICAL RESISTANCE CHART

This Chemical Resistance Chart is offered as a general guide to chemical attack. The ratings are based upon data from laboratory tests and published literature from the various manufacturers of rubber and polymers.

To select the proper glove for your chemical handling application, you must test to determine which liquid-proof type is most suitable. First determine the chemical and physical conditions present, then choose the glove with the highest performance ratings for those conditions.

You are now ready to test your selection under actual use conditions. You must determine suitability based on your own performance requirements.

Special Note: Those chemicals highlighted in bold type are considered known or suspected carcinogens. The chart indicates only comparative resistance to the degrading effect of these chemicals. Liquid and vapor permeation resistance is not considered in the ratings. The rate of permeation (the time required for a liquid or vapor to pass through the glove) is related to the thickness of the glove (the thicker the glove, the slower the rate) and the concentration of the chemical (the more concentrated the chemical, the quicker the liquid or vapor may pass through the glove). Permeation can occur even if there is no visible damage to the glove in question. Therefore, test for the presence of the liquid or vapor inside the glove to determine suitability.

The information contained in this chart is advisory only. Norton Company assumes no responsibility for the suitability of particular user glove selections.

Key to Chemical Chart:

- E. Excellent — Fluid has no effect
- G. Good — Fluid has minor effect
- F. Fair — Fluid has moderate effect
- P. Poor — Fluid has severe effect, ranging from moderate to complete destruction
- Blank — No data or insufficient evidence

Physical Performance Chart

PHYSICAL CHARACTERISTICS	NITRILE	BUTYL	NATURAL RUBBER	PVC	VITON
Abrasion Resistance	E	G	G	G	G
Cut Resistance	E	G	E	P	G
Puncture (Snag) Resistance	E	G	E	G	G
Flexibility	E	G	E	G	G
Heat Resistance	G	G	F	P	G
Ozone Resistance	F	G	P	E	E
Tensile Strength	E	G	E	F	G
Low Gas Permeability	P	E	F	P	E

Note: Products in these categories vary in capabilities. Laboratory tests are necessary for specific recommendations.

	UNSUPPORTED				SUPPORTED
CHEMICAL	VITON	NITRILE	BUTYL	NATURAL RUBBER	PVC
A					
Acetaldehyde	P	F	E	F	F
Acetic Acid	P	G	G	G	G
Acetone	P	P	E	G	P
Acrylonitrile	F	P	G	F	P
Aluminum Chloride	E	E	E	E	E
Ammonium Hydroxide	G	F	E	G	E
Amyl Acetate	P	P	E	F	P
Amyl Alcohol	G	G	E	G	—
Aniline	G	P	G	P	G
Animal Fats	E	E	G	P	G
B					
Benzaldehyde	P	P	E	F	F
Benzene	G	F	P	P	P
Benzyl Alcohol	E	P	G	P	—
Benzyl Chloride	E	P	F	P	—
Butane	E	E	P	P	P
Butyl Acetate	P	P	G	P	P
Butyl Alcohol	E	E	G	E	G
Butyraldehyde	P	P	G	P	G
C					
Calcium Hypochlorite	E	G	E	G	—
Carbolic Acid	E	P	G	P	—
Carbon Tetrachloride	E	G	P	P	P
Castor Oil	E	E	G	E	F
Chlorine (Dry)	G	P	F	P	—
Chlorine (Wet)	G	F	F	F	—
Chloroacetone	P	P	G	P	—
Chlorobenzene	E	P	P	P	P
Chloroform	E	P	P	P	P
Chromic Acid	E	P	P	P	G
Citric Acid	E	E	E	E	E
Cottonseed Oil	E	E	F	P	G
Creosote	E	G	P	P	G
Cutting Oil	E	E	F	F	F
Cyclohexane	E	E	P	P	F
Cyclohexanol	E	G	P	P	F
D					
Diacetone Alcohol	P	P	G	P	P
Dibenzyl	P	P	G	P	—
Dibutyl Phthalate	F	P	F	P	—
Diethylamine	P	F	G	F	F
Di-Isobutyl Ketone	—	P	E	G	P
Di-Isocyanate	—	G	—	P	F
Dimethyl Formamide	P	F	E	P	P
Dioxane	P	P	G	P	P
E					
Epoxy Resins	P	E	E	E	E
Ethyl Acetate	P	P	G	P	P
Ethyl Alcohol	G	E	E	E	G
Ethyl Ether	P	F	G	P	P
Ethyl Formate	E	P	G	P	P
Ethylene Dichloride	G	P	F	P	P
Ethylene Glycol	E	E	E	E	E
Ethylene Trichloride	E	P	F	P	—
F					
Fluorine	G	F	F	F	—
Formaldehyde	P	F	E	F	G

CHEMICAL	UNSUPPORTED VITON	NITRILE	BUTYL	NATURAL RUBBER	SUPPORTED PVC
F					
Formic Acid	F	F	E	E	E
Freon 11-12-21-22					
Freon 11	G	G	P	P	—
Freon 12	E	G	G	G	—
Freon 21	P	P	P	P	—
Freon 22	P	P	E	E	—
Furfural	P	P	G	P	P
G					
Gasoline	E	E	P	P	P
Glycerin	E	E	E	E	F
H					
Hexane	E	E	P	P	F
Hydraulic Fluid-Petroleum Base	E	E	P	P	G
Hydraulic Fluid-Ester Base	F	P	G	P	P
Hydrobromic Acid	E	P	E	E	—
Hydrochloric Acid 37%	E	G	E	G	G
Hydrofluoric Acid	G	F	G	F	F
Hydrogen Peroxide	E	F	G	F	F
Hydroquinone	G	F	P	G	F
I					
Isobutyl Alcohol	E	G	E	E	G
Iso-Octane	E	E	P	P	P
Isopropyl Alcohol	E	G	E	E	G
K					
Kerosene	E	E	P	P	F
L					
Lactic Acid	E	E	E	E	G
Lard	E	E	F	P	—
Linseed Oil	E	E	G	P	F
Lubricating Oils (Petroleum)	E	E	P	P	—
M					
Maleic Acid	E	P	P	P	G
Methyl Acetate	P	P	G	P	—
Methyl Alcohol	P	E	E	E	F
Methyl Bromide	E	G	F	F	P
Methyl Cellosolve	P	F	G	P	—
Methylene Chloride	G	P	F	P	P
Methyl Ethyl Ketone (M.E.K.)	P	P	E	G	P
Methyl Formate	—	P	G	P	—
Methyl Isobutyl Ketone	P	P	G	F	F
Methylamine	—	F	G	F	F
Methyl Methacrylate	P	P	F	P	F
Mineral Oil	E	E	P	P	F
Monoethanolamine	P	P	G	G	G
Morpholine	—	P	G	F	G
Muriatic Acid	—	G	E	G	G
N					
Naptha	E	E	P	P	P
Nitric Acid — Concentrated	G	P	F	P	F
Nitric Acid — Diluted	G	F	F	F	G

CHEMICAL	UNSUPPORTED VITON	NITRILE	BUTYL	NATURAL RUBBER	SUPPORTED PVC
N					
Nitric Acid — Red Fuming	F	P	P	P	P
Nitrobenzene	G	F	P	P	P
Nitromethane	P	P	G	G	P
O					
Octyl Alcohol	E	G	G	G	F
Oleic Acid	G	F	P	P	F
Olive Oil	E	E	G	P	F
Oxalic Acid	E	G	E	G	G
P					
Paint Remover	G	G	P	F	P
Pentane	E	E	P	P	P
Perchloric Acid	E	P	G	P	P
Perchloroethylene	E	F	P	P	P
Phenol	E	P	G	P	G
Phosphoric Acid	E	G	E	G	P
Pickling Solution	F	P	F	P	G
Picric Acid	E	G	G	G	G
Pine Oil	E	G	P	P	F
Plating Solutions — Chrome	E	E	E	G	E
Potassium Hydroxide (50%)	F	G	E	G	E
Printing Ink	—	E	—	G	F
Propane	E	E	P	P	F
Propyl Acetate	P	P	G	P	F
Propyl Alcohol	E	E	E	E	G
Propylene	E	P	P	P	—
S					
Skydrol 500	F	P	G	P	P
Sodium Hydroxide (50%)	G	G	E	E	E
Sodium Hypochlorite	E	G	E	G	—
Soybean Oil	E	E	F	P	—
Stearic Acid	—	G	G	G	G
Stoddard Solvent	E	E	P	P	F
Styrene	G	P	P	P	P
Sulfuric Acid (Diluted)	E	G	G	G	G
Sulfuric Acid (Concentrated)	E	P	G	P	F
T					
Tannic Acid	E	E	E	E	E
Tetrahydrofuran	P	P	G	P	P
Toluene	E	F	P	P	P
Toluene Di-Isocyanate	P	P	G	P	P
Trichlorethylene	E	F	P	P	P
Tricresyl Phosphate	G	P	E	P	P
Triethanol Amine	P	F	G	G	G
Trinitrotoluene	G	P	P	P	F
Tung Oil	E	E	F	P	F
Turbine Oil	E	G	P	P	P
Turpentine	E	E	P	P	F
V					
Vegetable Oil	E	E	E	P	F
Vinyl Chloride	G	—	—	—	—
X					
Xylene	E	F	P	P	P

Edmont®

Chemical Degradation

Chemical Degradation Guide is
ided as an aid in determining the
eral su:ability of various Edmont
es for use with specific chemicals.
dicates only the degrading effect
e chemicals on those materials.
es not consider permeability of the
erials, or the variable conditions
ch can influence product
ormance on actual job applications.
h variable conditions include
mical combinations, concentration,
perature, and the length of time the
duct is in contact with the chemical.
ddition, products of the same
erial but of different thicknesses
perform differently on the same
Since the actual use of the gloves
differ from that known to Edmont,
suitability of the product for a
cific job should be determined by
ng by the purchaser. Upon written
uest, Edmont will provide a sample
e material to aid you in making
determination.

CHEMICAL	RUBBER	NEOPRENE	POLYVINYL CHLORIDE PVC	POLYVINYL ALCOHOL PVA	NBR NITRILE
1. Acetaldehyde	E	E	NR	NR	P
2. Acetic Acid	E	E	F	NR	G
3. Acetone	E	G	NR	P	NR
4. Ammonium Hydroxide	E	E	E	NR	E
5. Amyl Acetate	P	NR	P	G	E
6. Aniline	G	G	F	F	NR
7. Benzaldehyde	F	NR	NR	G	NR
8. Benzene	NR	NR	NR	E	P
9. Butanol	E	E	G	F	E
10. Butyl Acetate	P	NR	NR	G	F
11. Carbon Disulfide	NR	NR	NR	E	G
12. Carbon Tetrachloride	NR	NR	F	E	G
13. Castor Oil	E	E	E	E	E
14. Chlorobenzene	NR	NR	NR	E	NR
15. Chloroform	NR	NR	NR	E	NR
16. Chloronapthalene	NR	NR	NR	G	P
17. Chromic Acid	NR	NR	G	NR	F
18. Citric Acid	E	E	E	F	E
19 Cyclohexanol	E	E	E	G	E
20 Dibutyl Phthalate	G	F	NR	E	G
21 Diethylamine	NR	P	NR	NR	F
22. Di-Isobutyl Ketone	P	P	P	G	E
23. Dimethyl Formamide	E	G	NR	NR	NR
24. Dioctyl Phthalate	F	G	NR	E	G
25. Dioxane	F	NR	NR	P	NR
26. Ethanol	E	E	G	NR	E
27 Ethyl Acetate	G	F	NR	F	NR
28. Ethylene Dichloride	P	NR	NR	E	NR
29. Ethylene Glycol	E	E	E	F	E
30. Ethyl Ether	NR	E	NR	G	E
31. Formaldehyde	E	E	E	P	E
32. Formic Acid 90%	E	E	E	NR	F
33. Freon	NR	G	NR	G	F
34 Furfural	E	G	NR	F	NR
35 Gasolene (white)	NR	NR	P	G	E
36. Glycerine	E	E	E	G	E
37. Hexane	NR	E	NR	G	E
38. Hydrazine 65%	G	E	E	NR	E
39. HCl 38%	G	E	E	NR	E
40 HCl 10%	E	E	E	NR	E
41. Hydrofluoric 48%	G	E	G	NR	E
42. Hydrogen Peroxide 30%	E	E	E	NR	E
43. Hydroquinone Saturated	G	E	E	NR	E
44. Isobutyl Alcohol	E	E	F	P	E
45. Iso-Octane	NR	E	P	E	E
46 Isopropanol	E	E	G	NR	E
47. Kerosene	F	E	F	G	E
48 Lactic Acid 85%	E	E	E	F	E

TED GLOVES PHYSICAL PERFORMANCE CHART

YSICAL PERFORMANCE	HYCRON	NEOX	REDMONT	SCORPIO	GRAB-IT	SNORKEL	GRAPPLER	MONKEY GRIP	PVA
sion Resistance	E	F	G	F	F	G	E	E	F
Resistance	G	E	E	G	E	F	F	F	F
Grip	E	G	G	G	E	E	G	E	G
bility	E	G	F	E	F	E	F	G	F
cture Resistance	E	E	E	F	E	G	G	G	F
Grip	F	F	G	E	G	E	E	F	F

O CHART: E – Excellent G – Good F – Fair P – Poor.

LIQUIDPROOF PROTECTION

uide For Gloves

CHEMICAL	RUBBER	NEOPRENE	POLYVINYL CHLORIDE PVC	POLYVINYL ALCOHOL PVA	NBR NITRILE
49. Lauric Acid 36%	G	E	F	NR	E
50. Linoleic Acid	P	E	G	G	E
51. Linseed Oil	F	E	E	G	E
52. Maleic Acid Saturated	E	E	G	NR	E
53. Methanol	E	E	G	NR	E
54. Methylamine	E	G	E	NR	E
55. Methylene Bromide	NR	NR	NR	G	NR
56. Methylene Chloride	NR	NR	NR	G	NR
57. Methyl Ethyl Ketone	G	P	NR	F	NR
58. Methyl Isobutyl Ketone	F	NR	NR	F	P
59. Methyl Methacrylate	P	NR	NR	G	P
60. Monethanolamine	E	E	E	F	E
61. Morpholine	E	P	NR	G	NR
62. Naphtha	NR	NR	F	E	E
63. Nitric Acid 70%	NR	G	F	NR	NR
64. Nitric Acid 10%	G	E	G	NR	E
65. Nitric Acid Red Fuming	P	NR	P	NR	NR
66. Nitric Acid White Fuming	NR	NR	P	NR	NR
67. Nitromethane 95.5%	E	E	P	G	F
68. Nitropropane 95.5%	E	G	NR	E	NR
69. Octyl Alcohol	E	E	F	G	E
70. Oleic Acid	F	E	F	G	E
71. Oxalic Acid Saturated	E	E	E	P	E
72. Palmitic Acid Saturated	G	E	G	P	G
73. Pentane	P	E	NR	G	E
74. Perchlorethylene	NR	NR	NR	E	G
75. Perchloric Acid 60%	F	E	E	NR	E
76. Phenol	E	E	G	F	NR
77. Phosphoric Acid	G	E	G	NR	E
78. Picric Acid Saturated	G	E	E	NR	E
79. Potassium Hydroxide 50%	E	E	E	NR	E
80. Propyl Acetate	F	P	NR	G	F
81. Propyl Alcohol	E	E	F	P	E
82. Propylene Oxide	P	NR	NR	G	NR
83. Sodium Hydroxide 50%	E	E	G	NR	E
84. Styrene	NR	NR	NR	G	NR
85. Sulfuric Acid 95%	NR	F	G	NR	NR
86. Tannic Acid 65%	E	E	E	P	E
87. Tetrahydrofuran	NR	NR	NR	P	NR
88. Toluene	NR	NR	NR	G	F
89. Toluene Di-Isocyanate	F	NR	P	G	NR
90. Trichlorethylene	NR	NR	NR	E	NR
91. Tricresyl Phosphate	E	F	F	G	E
92. Triethanolamine 85%	G	E	E	G	E
93. Tung Oil	NR	E	F	E	E
94. Turpentine	NR	NR	P	G	E
95. Xylene	NR	NR	NR	E	G

SPECIAL NOTE

The Guide indicates only the degrading effect of these chemicals on product materials. Permeability of the product materials by these chemicals is not considered.

KEY TO DEGRADATION GUIDE:

E – Fluid has very little degrading effect.

G – Fluid has minor degrading effect.

F – Fluid has moderate degrading effect.

P – Fluid has pronounced degrading effect.

NR – Fluid is not recommended with this materi

TESTING PROCEDURE

Films of the test material were made. These films were weighed and measured and then completely immersed in the test chemical for 30 minutes. The percentage of change in size was determined and then films were dried to calculat the percentage of weight change. Observed physical changes were also recorded. Ratings were based on the combined data.

Edmont LIQUIDPROOF GLOVES

RUBBER	• Tan Rubber
RUBBER	• Long Service Rubber
RUBBER	• Grab-it (Liquidproof Style)
RUBBER	• Premium White Rubber
NEOPRENE	• Neoprene
NEOPRENE	• Scorpio
NEOPRENE	• Neox
NEOPRENE	• Redmont
PVC	• Grappler (Liquidproof Styles)
PVC	• Snorkel
PVC	• Ever-Flex
PVC	• Ever-Flex Fireball
PVC	• Monkey Grip
PVC	• Winter Monkey Grip (Up to Knitw
PVC	• Winter Fireball (Up to Knitwrist)
PVA	• PVA (CAUTION: COATING IS WATER SOLUBLE)
NBR	• Sol-Vex

SPECIAL NOTE

The chemicals in the above Guide highlighted in Blue, in the chemical column, denote recognized human car inogens*. Those shown in green have been identified as si spected human carcinogens. The Guide indicates only tl a degrading effect of these chemicals on product materials. 'ermeability the product materials by these chemicals is not .onsidered.

*(5th Edition) *Dangerous Properties of Industrial Materials* by N. Irving Sax

UNSUPPORTED GLOVES
PHYSICAL PERFORMANCE CHART

Physical Characteristics	Neoprene	Rubber	NBR	Vinyl
Tensile Strength	E	E	E	F
Elongation	E	E	G	F
Tear Resistance	G	G	G	F
Abrasion Resistance	G	G	E	G
Heat Resistance	E	F	E	P
Ozone Resistance	E	G	G	E

KEY TO CHART: E – Excellent G – Good F – Fair P – Poor.

Chemical resistance offered by Fyrepel Fire/Chemical Suits.

Chemical	PVC	Viton	Butyl
Acetaldehyde	I	P	E
Acetic Acid	P	P	G
Acetone	P	P	E
Acrylonitrile	P	F	G
Aluminum Chloride	GF	E	E
Ammonium Hydroxide	E	G	E
Amyl Acetate	P	P	E
Amyl Alcohol	E	G	E
Aniline	P	G	G
Animal Fats	GF	E	G
Benzaldehyde	P	P	E
Benzene	FP	G	P
Benzyl Alcohol	P	E	G
Benzyl Chloride	P	E	F
Butane	GF	E	P
Butyl Acetate	P	P	G
Butyl Alcohol	GF	E	G
Butyraldehyde	P	P	G
Calcium Hypochlorite	E	E	E
Carbolic Acid	E	E	G
Carbon Tetrachloride	P	E	P
Castor Oil	GF	E	G
Chlorine (Dry)	GF	G	F
Chlorine (Wet)	P	G	F
Chloroacetone	P	P	G
Chlorobenzene	P	E	P
Chloroform	P	E	P
Chromic Acid	E	E	P
Citric Acid	E	E	E
Cottonseed Oil	E	E	F
Creosote	FP	E	P
Cutting Oil	I	E	F
Cyclohexane	GF	E	P
Cyclohexanol	FP	E	P
Diacetone Alcohol	FP	P	G
Dibenzyl	F	P	G
Dibutyl Phthalate	P	F	F
Diethylamine	GF	P	G
Di-Isobutyl Ketone	I	I	E
Di-Isocyanate	I	I	I
Dimethyl Formamide	P	P	E
Dioxane	P	P	G
Epoxy Resins	I	P	E
Ethyl Acetate	P	P	G
Ethyl Alcohol	GF	G	E
Ethyl Ether	P	P	G
Ethyl Formate	GF	E	G
Ethylene Dichloride	P	G	F
Ethylene Glycol	E	E	E
Ethylene Trichloride	FP	E	F

Chemical	PVC	Viton	Butyl
Fluorine	I	G	F
Formaldehyde	E	P	E
Formic Acid	GF	F	E
Freon 11	FP	G	P
Freon 12	E	E	G
Freon 21	I	P	P
Freon 22	E	P	E
Furfural	P	P	G
Gasoline	FP	E	P
Glycerin	E	E	E
Hexane	GF	E	P
Hydraulic Fluid—Petroleum Base	I	E	P
Hydraulic Fluid—Ester Base	F	F	G
Hydrobromic Acid	E	E	E
Hydrochloric Acid 37%	E	E	E
Hydrofluoric Acid	E	G	G
Hydrogen Peroxide	E	E	G
Hydroquinone	E	G	P
Isobutyl Alcohol	GF	E	E
Iso-Octane	GF	E	P
Isopropyl Alcohol	E	E	E
Kerosene	GF	E	P
Lactic Acid	E	E	E
Lard	E	E	F
Linseed Oil	GF	E	G
Lubricating Oils (Petroleum)	GF	E	P
Maleic Acid	E	E	P
Methyl Acetate	P	P	G
Methyl Alcohol	E	P	E
Methyl Bromide	I	E	F
Methyl Cellosolve	E	P	G
Methylene Chloride	P	G	F
Methyl Ethyl Ketone (M.E.K.)	P	P	E
Methyl Formate	GF	I	G
Methyl Isobutyl Ketone	P	P	G
Methylamine	I	I	G
Methyl Methacrylate	P	P	F
Mineral Oil	E	E	P
Monoethanolamine	I	P	G
Morpholine	I	I	G
Muriatic Acid	I	I	E
Naptha	FP	E	P
Nitric Acid—Concentrated	P	G	F
Nitric Acid—Diluted	GF	G	F
Nitric Acid—Red Fuming	P	F	P
Nitrobenzene	P	G	P
Nitromethane	I	P	G

Chemical	PVC	Viton	Butyl
Octyl Alcohol	E	E	G
Oleic Acid	E	G	P
Olive Oil	E	E	G
Oxalic Acid	E	E	E
Paint Remover	F	G	P
Pentane	I	E	P
Perchloric Acid	I	E	G
Perchloroethylene	P	E	P
Phenol	FP	E	G
Phosphoric Acid	I	E	E
Phosphoric Acid (20%, 45%)	E	E	E
Pickling Solution	E	F	F
Picric Acid	E	E	G
Pine Oil	GF	E	P
Plating Solutions—Chrome	I	E	E
Potassium Hydroxide (50%)	E	F	E
Printing Ink	I	I	I
Propane	FP	E	P
Propyl Acetate	FP	P	G
Propyl Alcohol	E	E	E
Propylene	E	E	P
Skydrol 500	I	F	G
Sodium Hydroxide (50%)	GF	G	E
Sodium Hypochlorite	GF	E	E
Soybean Oil	E	E	F
Stearic Acid	E	I	G
Stoddard Solvent	FP	E	P
Styrene	P	G	P
Sulfuric Acid (Diluted)	E	E	G
Sulfuric Acid (Concentrated)	E	E	G
Tannic Acid	E	E	E
Tetrahydrofuran	P	P	G
Toluene	P	E	P
Toluene Di-Isocyanate	FP	P	G
Trichlorethylene	P	E	P
Tricresyl Phosphate	FP	G	E
Triethanol Amine	GF	P	G
Trinitrotoluene	FP	G	P
Tung Oil	FP	E	F
Turbine Oil	FP	E	P
Turpentine	FP	E	P
Vegetable Oil	FP	E	E
Vinyl Chloride	P	G	I
Xylene	P	E	P

E — No Effect
G — Minor Effect
F — Moderate Effect
P — Severe Effect
I — Insufficient Data Available

WARRANTY—Goods sold by Fyrepel shall be free from defects in workmanship and materials. No use warranty is implied or intended. Technical advice on typical applications is offered without obligation or liability

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Fyrepel™
PROTECTIVE WEAR

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ILC's Chemturion™ Chemical Protective Suit

ILC DOVER CHEMICAL COMPATIBILITY CHART

As a service to our customers ILC Dover has prepared this Chemical Compatibility Chart as a reference in selecting protective suit materials. While ILC Dover believes the chart represents reasonably accurate data, we do not guarantee its accuracy nor do we assume responsibility for its use. We recommend testing materials against the chemical(s) in question before use. ILC Dover provides free sample material swatches for such testing.

MATERIALS ON THE CHART

CPE (Chlorinated Polyethylene) - This chlorinated polyethylene has reduced flammability and increased resistance to oil, ozone, heat and chemicals. It has good to excellent resistance to aliphatic hydrocarbons, phenols, ketones, esters, acids, bases, and salts. CPE provides very low permeability to gases.

F.R. Urethane (Flame Retardant Urethane) - Polyurethanes are fairly resistant to many chemicals such as aliphatic solvents, alcohols, ether, certain fuels and oils. This urethane has the added feature of flame retardance as specified in UL Vertical Flame Test Method 94.

Viton - Viton is a specialty fluoroelastomer. Generally, it has excellent resistance to oils, fuels, lubricants, most mineral acids, hydraulic fluids, and aliphatic and aromatic hydrocarbons.

Butyl - Butyl is not resistant to oil, grease or flame. It does have good resistance to ketones, esters, most acids and bases, and inorganic salts. Butyl has excellent impermeability to gases.

Vinyl (PVC) - Polyvinyl Chloride has good to excellent resistance to amines and aromatics, inorganic acids, bases and salts. However, this low-cost elastomer has poor resistance to halogenated hydrocarbons, ketones and esters.

Nitrile (NBR) - Nitrile polymers are practically unaffected by alkaline solutions, saturated salt solutions and aliphatic hydrocarbons, both saturated and unsaturated. They are affected little by fatty acids found in vegetable fats and oils or by aliphatic alcohols, glycols or glycerols. Nitrile rubber is not recommended, generally, for use in the presence of strong oxidizing agents, ketones, acetates, and a few other chemicals.

Neoprene - In general, neoprene compounds have excellent resistance to all straight-chain hydrocarbons, all aliphatic hydroxy compounds such as methyl and ethyl alcohols and ethylene glycol, animal and vegetable fats and oils, and fluorinated hydrocarbons such as Freon refrigerants.

RATING KEY

A - RECOMMENDED (Little or no effect)
B - MINOR TO MODERATE EFFECT
C - CONDITIONAL (Varies from moderate to severe under different conditions)
X - NOT RECOMMENDED (Severe effect)
I - INSUFFICIENT DATA TO RATE

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Acetaidehyde	B	X	X	A	X	X	C
Acetamide	B	X	B	A	B	A	B
Acetic Acid, Anhydride	A	X	X	B	X	C	A
Acetic Acid, 30%	A	X	B	B	B	B	A
Acetic Acid, Glacial	A	X	C	B	C	C	X
Acetone	A	X	X	A	X	X	B
Acetophenone	X	X	X	A	X	X	X
Acetyl Chloride	A	X	A	C	X	X	X
Acetylene	A	B	A	A	A	B	B
Acrylamide	A	I	I	A	B	A	A
Acrylonitrile	A	X	X	X	X	X	C
Adipic Acid	A	A	A	A	A	A	A
Alkazene	X	X	B	X	X	X	X
Allyl Alcohol	A	C	A	A	A	A	A
Alum-NH_3-Cr-K	I	X	X	A	I	A	A
Aluminum Acetate	A	X	A	A	A	B	B
Aluminum Chloride	A	B	A	A	B	A	A
Aluminum Fluoride	A	C	A	A	B	A	A
Aluminum Hydroxide	A	A	A	B	B	A	A
Aluminum Nitrate	A	C	A	A	A	A	A
Aluminum Phosphate	A	A	A	A	A	A	A
Aluminum Sulfate	A	A	A	A	A	A	A
Ammonia Anhydrous	A	X	X	A	A	B	A
Ammonia Gas (Cold)	A	C	A	A	A	A	A
Ammonia Gas (Hot)	B	X	B	B	B	X	A
Ammonium Carbonate	A	B	A	A	A	X	A
Ammonium Chloride	A	A	A	A	B	A	A
Ammonium Hydroxide	A	X	B	A	A	C	A
Ammonium Nitrate	A	X	A	A	A	A	B
Ammonium Nitrate	A	C	A	A	A	A	A
Ammonium Persulfate	A	X	A	A	A	X	A
Ammonium Phosphate	A	A	A	A	A	A	A
Ammonium Salts	A	I	A	A	A	A	A
Ammonium Sulfate	A	A	A	A	A	A	A
Amyl Acetate	C	X	X	A	X	X	X
Amyl Alcohol	A	X	B	A	A	B	A
Amyl Borate	I	I	A	X	I	A	A
Amyl Chloronapthalene	I	X	A	X	I	X	X
Aniline	B	X	C	B	X	X	X
Aniline Dyes	I	X	B	B	I	X	B
Aniline Hydrochloride	A	X	B	B	A	B	X
Animal Fats	A	B	A	B	B	A	B
Ansul Ether	I	B	X	C	I	C	X
Aqua Regia	C	X	B	X	C	X	X
Arochlor(s)	C	X	A	C	C	C	X

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Arsenic Acid	A	C	A	A	A	A	A
Arsenic Trichloride	B	B	A	C	B	A	A
Askarel	C	X	A	X	B	B	X
Asphalt	A	B	A	X	B	B	C
Barium Chloride	A	A	A	A	A	A	A
Barium Hydroxide	A	A	A	A	A	A	A
Barium Sulfide	A	A	A	A	A	A	A
Benzaldehyde	C	X	X	A	X	X	X
Benzene	C	C	A	X	C	X	X
Benzene Sulfonic Acid	A	X	A	X	A	X	A
Benzoic Acid	A	X	A	X	B	X	X
Benzyl Chloride	X	X	X	X	X	X	X
Benzyl Alcohol	A	X	A	B	X	X	B
Benzyl Benzoate	A	C	A	B	A	X	X
Benzyl Chloride	X	X	A	X	X	X	X
Berrylium	A	A	A	A	A	A	A
Black Sulfate Liquor	A	C	A	B	A	B	B
Blast Furnace Gas	A	X	A	X	A	X	X
Bleach Solutions	A	X	A	A	A	X	C
Borax	A	A	A	A	A	B	A
Bordeaux Mixture	A	X	A	A	A	B	B
Boric Acid	A	A	A	A	A	A	A
Boron Trifluoride	C	C	C	C	B	C	C
Brine	A	B	A	A	A	A	A
Bromine	A	X	A	X	A	X	X
Butadiene	B	C	B	X	B	X	B
Butane	B	A	A	X	B	A	A
Butter	A	A	A	B	A	A	B
Butyl Acetate	X	X	X	B	X	X	X
Butyl Acetyl Ricinoleate	A	X	A	A	A	C	B
Butyl Acrylate	C	X	X	X	X	X	X
Butyl Alcohol	A	X	A	B	B	A	A
Butyl Amine	B	X	X	X	X	C	X
Butyl Benzoate	B	X	A	B	B	X	X
Butyl Carbitol	B	B	A	A	B	B	B
Butyl Cellosolve	B	X	X	A	B	C	C
Butyl Oleate	A	A	A	B	A	X	X
Butyl Stearate	B	C	A	B	B	B	X
Butyraldehyde	B	X	X	B	X	X	C
Butyric Acid	A	A	A	B	A	X	X
Calcuim Acetate	A	X	X	A	A	B	B
Calcium Bisulfite	A	A	A	X	A	A	A
Calcium Chloride	A	A	A	A	A	A	A

Rating Key: A-Recommended Little or no effect B-Minor to moderate effect C-Conditional - Varies from moderate to severe under different conditions X-Not Recommended Severe effect I-Insufficient data to rate

These ratings are predicated upon exposures as anticipated in chemical spills and other intermediate exposure and are not indicative of long term immersion resistance

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Calcium Hydroxide	A	A	A	A	A	A	A
Calcium Hypochlorite	A	X	A	A	A	C	C
Calcium Nitrate	A	A	A	A	A	A	A
Calcium Sulfide	A	A	A	A	A	B	A
Cane Sugar Liquors	A	X	A	A	A	A	A
Carbamate	A	X	A	B	A	C	B
Carbitol	A	C	B	B	B	B	B
Carbolic Acid	A	C	A	B	A	X	C
Carbon Bisulfide	X	X	A	X	X	C	X
Carbon Dioxide	A	A	A	B	A	A	B
Carbon Disulfide	X	X	X	X	X	X	X
Carbonic Acid	A	A	A	A	A	B	A
Carbon Monoxide	A	A	A	A	A	A	A
Carbon Tetrachloride	C	X	A	X	X	C	X
Castor Oil	A	A	A	B	B	A	A
Cellosolve	B	X	C	B	B	X	X
Cellosolve Acetate	B	X	X	B	B	X	X
Cellulube	A	B	A	A	B	X	X
Chlorinated Solvents	X	I	I	X	X	X	X
Chlorine (Dry)	A	X	A	X	B	X	C
Chlorine (Wet)	A	X	A	C	X	X	X
Chlorine Dioxide	A	X	A	C	A	X	X
Chlorine Trifluoride	B	X	X	X	B	X	X
Chloroacetic Acid	A	X	A	B	A	X	X
Chloroacetone	X	X	X	B	X	X	B
Chlorobenzene	X	C	A	X	X	X	X
Chlorobromomethane	X	I	X	B	X	X	X
Chlorobutadiene	I	I	A	X	I	X	X
Chlorododecane	A	I	A	X	C	X	X
Chloroform	X	X	A	X	X	X	X
O-Chloronaphthalene	A	X	A	X	C	X	X
1-Chloro 1-Nitro Ethane	X	X	X	X	X	X	X
Chlorox Solution	A	C	A	B	B	B	A
Chlorosulfonic Acid	A	X	C	X	A	X	X
Chlorotoluene	C	I	A	X	B	X	X
Chrome Plating Solutions	A	X	A	X	A	X	X
Chromic Acid	A	X	A	C	A	X	X
Citric Acid	A	A	A	A	A	A	A
Coal Tar Products	C	C	C	X	C	A	B
Cobalt Chloride	A	X	A	A	A	A	A
Cocoanut Oil	A	A	A	B	A	A	B
Cod Liver Oil	A	A	A	A	A	A	B
Coke Oven Gas	B	X	A	X	B	X	X
Copper Acetate	A	X	A	A	A	B	B

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Copper Chloride	A	A	A	A	A	A	A
Copper Cyanide	A	A	A	A	A	A	A
Copper Sulfate	A	A	A	B	A	A	A
Corn Oil	A	A	A	C	A	A	C
Cottonseed Oil	A	A	A	C	A	A	B
Creosote	C	B	A	X	C	B	C
Cresol	A	X	A	X	C	X	C
Cresylic Acid	A	X	A	X	A	X	C
Cumene	B	X	A	X	B	X	X
Cyclohexane	A	B	A	X	B	A	X
Cyclohexanol	A	C	A	X	C	B	B
Cyclohexanone	X	X	X	B	X	X	X
P-Cymene	X	X	A	X	X	X	X
Decalin	C	C	A	X	C	X	X
Decane	B	B	A	X	C	B	B
Denatured Alcohol	A	X	A	A	B	A	A
Detergent Solutions	A	X	A	A	B	A	B
Developing Fluids	A	C	A	B	A	A	A
Diacetone Alcohol	A	X	I	A	C	X	B
Dibenzyl Ether	C	B	I	B	C	X	C
Dibenzyl Sebecate	C	B	B	B	C	X	X
Dibutyl Amine	A	X	X	X	B	B	B
Dibutyl Ether	A	B	C	C	X	X	C
Dibutyl Phthalate	C	C	B	C	X	X	X
Dibutyl Sebacate	B	C	B	B	X	X	X
O-Dichloro Benzene	X	C	A	X	X	X	X
Dichloro-Isopropyl Ether	C	X	C	X	C	X	X
Diesel Oil	A	A	A	X	A	A	B
Diethyl Amine	B	C	X	B	B	C	C
Diethyl Ether	A	C	X	X	C	X	C
Diethylene Glycol	A	C	A	A	B	A	A
Diethyl Sebacate	C	C	B	B	C	X	X
Diisobutylene	C	C	A	X	C	B	X
Diisopropyl Benzene	C	B	A	X	C	X	X
Diisopropyl Ketone	C	X	X	A	C	X	X
Dimethyl Aniline	C	X	X	X	C	X	X
Dimethyl Formamide	C	X	X	B	X	B	C
Dimethyl Phthalate	A	C	B	B	B	X	X
Dinitro Toluene	C	X	C	X	C	X	X
Dioctyl Phthalate	C	X	B	B	C	C	X
Dioctyl Sebacate	C	B	B	B	C	X	X
Dioxane	B	X	C	B	X	X	X
Dioxolane	C	X	X	C	C	X	X

Rating Key: A-Recommended Little or no effect B-Minor to moderate effect C-Conditional - Varies from moderate to severe under different conditions X-Not Recommended Severe effect I- Insufficient data to rate

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Dowtherm Oil	C	B	A	X	C	X	X
Dry Cleaning Fluids	B	B	A	X	C	C	X
Epichlorohydrin	I	X	X	B	I	X	X
Ethane	B	B	A	X	B	A	B
Ethanolamine	A	C	X	B	A	B	B
Ethyl Acetate	B	X	X	B	X	X	C
Ethyl Acetoacetate	A	X	X	B	A	X	C
Ethyl Acrylate	B	X	X	B	X	X	X
Ethyl Alcohol	A	X	A	A	B	A	A
Ethyl Benzene	C	X	A	X	B	X	X
Ethyl Benzoate	I	X	A	B	I	X	X
Ethyl Bromide	C	I	I	X	X	B	X
Ethyl Chloride	C	B	A	A	C	A	B
Ethyl Ether	B	B	X	C	X	C	X
Ethyl Formate	A	C	A	B	B	X	B
Ethyl Mercaptan	B	C	A	X	B	X	C
Ethyl Oxalate	A	A	A	A	B	X	C
Ethyl Silicate	A	A	A	A	A	A	A
Ethylene	A	A	A	B	A	A	C
Ethylene Chloride	I	X	A	C	I	X	X
Ethylene Chlorohydrin	I	X	A	B	I	X	B
Ethylene Diamine	B	X	X	A	B	A	A
Ethylene Dibromide	C	X	C	C	X	X	X
Ethylene Dichloride	C	X	A	C	X	X	X
Ethylene Glycol	A	B	A	A	A	A	A
Ethylene Oxide	A	X	X	C	X	X	X
Ethylene Trichloride	C	X	A	C	C	X	X
Fatty Acids	A	A	A	C	A	B	B
Ferric Chloride	A	A	A	A	A	A	A
Ferric Nitrate	A	A	A	A	A	A	A
Ferric Sulfate	A	A	A	A	A	A	A
Fish Oil	A	A	A	X	A	A	X
Fluoroboric Acid	A	A	A	A	A	A	A
Fluorine (Liquid)	X	X	B	C	X	X	X
Fluorocarbon Oils	A	A	B	A	A	A	B
Fluorolube	A	A	B	A	A	A	A
Fluorosilicic Acid	A	A	B	B	C	A	A
Formaldehyde	A	C	A	A	A	C	B
Formic Acid	A	C	C	A	B	B	A
Freon 11	C	X	A	X	C	B	C
Freon 12	A	A	B	B	A	A	A
Freon 13	A	A	A	A	A	A	A
Freon 21	I	X	X	X	I	A	X
Freon 22	A	X	X	A	A	X	A

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPR
Freon 31	I	I	X	A	I	X	A
Freon 32	I	I	C	A	I	A	A
Freon 112	I	B	A	X	I	B	X
Freon 113	B	B	B	X	B	A	A
Freon 114	B	A	B	A	B	A	A
Freon 115	B	B	B	A	B	A	A
Freon 142B	B	I	X	A	I	A	A
Freon 152A	I	I	X	A	I	A	A
Freon 218	B	A	A	A	B	A	A
Freon C316	B	B	A	A	B	A	A
Freon C318	B	B	A	A	B	A	A
Freon 114B2	I	C	B	X	I	B	B
Freon 502	I	C	B	A	I	B	A
Freon TA	B	A	B	A	B	A	A
Freon TC	B	A	B	A	B	A	A
Freon TF	C	A	A	X	C	A	A
Freon TMC	C	B	A	B	C	B	B
Freon T-P35	B	A	A	A	B	A	A
Freon T-WD602	B	A	A	A	B	B	B
Freon BF	I	I	I	X	I	B	B
Freon MF	I	I	I	X	I	A	C
Fuel Oil	B	A	A	X	B	A	B
Fumaric Acid	A	I	A	X	A	A	B
Furan	A	I	X	X	A	X	X
Furfural	A	C	X	B	X	X	C
Gallic Acid	A	X	A	B	B	B	B
Gasoline	B	A	A	X	C	A	B
Glucose	A	A	A	A	A	A	A
Glue (Water Base)	A	A	A	A	A	A	A
Glycerine	A	B	A	A	A	A	A
Glycols	A	B	A	A	A	A	A
Green Sulfate Liquor	A	A	A	A	A	B	B
Halowax Oil	A	A	A	X	A	X	X
N-Hexaldehyde	C	I	I	B	C	X	A
Hexane	A	A	A	X	B	A	B
N-hexene-1	I	B	A	X	I	B	B
Hexyl Alcohol	A	X	A	C	B	A	B
Hexylene Glycol	A	I	A	A	B	B	B
Hydraulic Oil	C	A	A	X	C	A	B
Hydrazene	X	X	I	A	I	C	C
Hydrobromic Acid	A	X	A	A	A	X	B
(37%) Hydrochloric Acid (Hot)	A	X	A	C	A	X	X
(37%) Hydrochloric Acid (Cold)	A	X	A	A	A	B	B

Rating Key: A Recommended Little or no effect B Minor to moderate effect C Conditional Varies from moderate to severe under different conditions X Not Recommended Severe effect I Insufficient data to rate

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Hydrocyanic Acid	A	I	A	A	B	B	B
Hydrofluoric Acid (Hot)	A	X	B	X	A	X	X
Hydrofluoric Acid (Cold)	A	C	A	B	A	X	B
Hydrogen Gas	A	A	A	A	A	A	A
Hydrogen Peroxide (90%)	A	I	B	C	A	X	X
Hydrogen Sulfide (Cold)	A	A	X	A	A	X	A
Hydrogen Sulfide (Hot)	A	I	X	A	A	X	B
Hydroquinone	A	C	X	X	A	C	X
Iodine	A	A	A	B	A	B	X
Isobutyl Alcohol	A	X	A	A	B	B	A
Isooctane	A	B	A	X	B	A	B
Isophorone	C	C	X	A	X	X	X
Isopropyl Acetate	C	X	X	B	X	X	X
Isopropyl Alcohol	A	C	A	A	A	B	B
Isopropyl Chloride	A	X	A	X	A	X	X
Isopropyl Ether	A	C	X	X	A	B	C
JP3	A	A	A	X	C	A	X
JP4	A	A	A	X	C	A	X
Kerosene	A	A	A	X	B	A	C
Lacquers	X	X	X	X	X	X	X
Lacquer Solvents	X	X	X	C	X	X	X
Lactic Acid	A	X	A	A	A	A	A
Lard	A	A	A	X	A	A	C
Lead Acetate	A	X	A	A	A	B	B
Lead Nitrate	A	A	A	A	A	A	A
Lead Sulfamate	A	A	A	A	A	B	A
Lime Bleach	A	A	A	A	A	A	B
Lime Sulfur	A	A	A	A	A	X	A
Lindol	C	X	B	A	C	X	X
Linoleic Acid	A	A	B	X	A	B	X
Linseed Oil	A	B	A	C	B	A	B
Liquified Petroleum Gas	A	A	A	X	A	A	B
Lubricating Oils	A	A	A	X	B	A	B
Lye	A	X	B	A	A	B	B
Magnesium Chloride	A	A	A	A	A	A	A
Magnesium Hydroxide	A	X	A	A	A	B	A
Magnesium Sulfate	A	A	A	A	A	A	A
Malathion	C	I	I	X	B	B	B
Maleic Acid	A	A	A	C	A	X	X
Maleic Anhydride	A	A	A	C	A	X	X
Malic Acid	A	A	A	X	A	A	B
Mercuric Chloride	A	I	A	A	X	A	A

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Mercury	A	A	A	A	A	A	A
Mesityl Oxide	C	X	X	B	X	X	X
Methane	A	C	A	X	A	A	B
Methyl Acetate	A	X	X	B	X	X	B
Methyl Alcohol	A	X	C	A	A	A	A
Methyl Acrylate	C	X	X	B	C	X	B
Methylacrylic Acid	B	X	B	B	B	X	B
Methyl Bromide	I	I	A	X	I	B	X
Methyl Butyl Ketone	I	X	X	A	I	X	X
Methyl Cellosolve	A	X	X	B	A	B	B
Methyl Chloride	C	X	A	C	C	X	X
Methyl Ethyl Ketone	C	X	X	A	X	X	X
Methyl Methacrylate	C	X	X	X	X	X	X
Methylene Chloride	C	X	B	X	X	X	X
Methyl Formate	B	X	I	B	B	X	B
Methyl Isobutyl Ketone	C	X	X	C	X	X	X
Methyl Oleate	A	A	A	B	A	X	X
Methyl Salicylate	I	I	I	B	I	X	X
Milk	A	B	A	A	A	A	A
Mineral Oil	A	A	A	X	A	A	B
Monochlorobenzene	C	X	A	X	C	X	X
Monomethyl Aniline	C	X	B	B	C	X	X
Monoethanol Amine	I	X	X	B	I	X	X
Monomethyl Ether	B	B	B	A	B	A	A
Monovinyl Acetylene	C	B	A	A	C	A	B
Mustard Gas	A	X	I	A	A	A	A
Naphtha	A	B	A	X	C	C	C
Naphthalene	A	B	A	X	X	X	X
Natural Gas	A	B	A	X	A	A	A
Neville Acid	A	I	A	B	A	X	X
Nickel Acetate	A	X	X	A	A	B	B
Nickel Chloride	A	C	A	A	A	A	A
Nickel Sulfate	A	C	A	A	A	A	A
Nitric Acid-Conc.	X	X	A	C	X	X	X
Nitric Acid-Dilute	A	C	A	B	B	X	A
Nitric Acid-Red Fuming	X	X	C	X	X	X	[illegible]
Nitrobenzene	C	X	B	C	X	X	
Nitroethane	A	X	X	B	X	X	
Nitromethane	I	X	X	B	I	X	
Nitrogen	A	A	A	A	A	A	
Nitrogen Tetroxide	C	X	X	C	C	X	
Octadecane	A	A	A	X	C	A	
N-Octane	A	A	A	X	C	A	

Rating Key: A Recommended Little or no effect B Minor to moderate effect C Conditional Varies from moderate to severe under different conditions X Not Recommended Severe effect I Insufficient data to rate

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Octachlorotoluene	A	A	A	X	C	X	X
Octyl Alcohol	A	B	A	B	A	B	A
Oleic Acid	A	B	B	B	A	C	C
Oleum Spirits	A	C	A	X	A	B	C
Olive Oil	A	A	A	B	A	A	B
Oxalic Acid	A	A	A	A	A	B	B
Oxygen-Cold	A	A	A	A	A	B	A
Oxygen-200-400 °F	X	X	B	X	I	X	X
Ozone	A	A	A	B	B	X	C
Paint Thinner, Duco	C	X	B	X	C	X	X
Palmitic Acid	A	A	A	B	A	A	B
Peanut Oil	A	A	A	C	B	A	B
Perchloric Acid	I	X	A	B	I	X	B
Perchloroethylene	C	B	A	X	X	C	X
Petroleum-Below 250°	A	A	A	X	C	A	B
Petroleum-Above 250°	X	X	B	X	X	C	X
Phenol	A	C	A	B	C	X	C
Phenyl Benzene	B	X	A	X	B	X	X
Phenyl Ethyl Ether	B	X	B	X	B	X	X
Phenyl Hydrazine	I	I	I	X	I	X	X
Phorone	I	X	I	B	I	X	X
Phosphoric Acid (20%)	A	A	A	B	A	B	B
Phosphoric Acid (45%)	A	A	A	B	A	X	B
Phosphorous Trichloride	A	A	A	A	A	X	X
Pickling Solution	A	X	B	C	A	X	X
Picric Acid	A	B	A	B	A	B	A
Pinene	B	B	A	X	B	B	C
Pine Oil	B	B	A	X	B	B	X
Piperidene	C	X	X	X	C	X	X
Polyvinyl Acetate Emulsion	A	B	A	A	A	A	B
Potassium Acetate	A	I	I	A	A	B	B
Potassium Chloride	A	A	A	A	A	A	A
Potassium Cupro Cyanide	A	A	A	A	A	A	A
Potassium Cyanide	A	A	A	A	A	A	A
Potassium Dichromate	A	B	A	A	A	A	A
Potassium Hydroxide	A	B	B	A	A	B	B
Potassium Nitrate	A	A	A	A	A	A	A
Potassium Sulfate	A	A	A	A	A	A	A
Propane	C	C	A	X	C	A	B
Propyl Acetate	C	X	X	B	C	X	X
Propyl Alcohol	A	B	A	A	A	A	A
N-Propyl Acetate	B	X	X	A	B	X	X
Propyl Acetone	B	X	X	A	B	X	X
Propyl Nitrate	I	I	X	B	I	X	X

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Propylene	A	I	A	X	A	X	X
Propylene Oxide	I	X	I	B	I	X	X
Pyranol	C	B	A	X	C	A	X
Pyridine	C	X	X	B	C	X	X
Pyrrole	C	I	I	X	C	X	X
Radiation	B	A	X	X	B	C	B
Rape Seed Oil	A	B	A	A	A	B	B
Red Oil	A	B	A	X	B	A	B
Sal Ammoniac	A	A	A	A	A	A	A
Salicylic Acid	A	A	A	A	A	B	A
Salt Water	A	B	A	A	A	A	A
Sewage	A	B	A	B	A	A	B
Silicate Esters	C	A	A	X	C	B	A
Silicone Greases	A	A	A	A	A	A	A
Silicone Oils	A	A	A	A	A	A	A
Silver Nitrate	A	A	A	A	A	B	A
Skydrol 500	B	X	X	B	I	X	X
Skydrol 7000	B	X	B	A	I	X	X
Soap Solutions	A	A	A	A	A	A	A
Soda Ash	A	A	A	A	A	A	A
Sodium Bicarbonate	A	A	A	A	A	A	A
Sodium Acetate	A	I	I	A	A	B	B
Sodium Bisulfite	A	A	A	A	A	A	A
Sodium Borate	A	A	A	A	A	A	A
Sodium Carbonate	A	A	A	A	A	A	A
Sodium Chloride	A	A	A	A	A	A	A
Sodium Cyanide	A	A	A	A	A	A	A
Sodium Hydroxide	A	X	B	A	B	B	A
Sodium Hypochlorite	A	X	A	B	B	B	B
Sodium Metaphosphate	A	A	A	A	A	A	B
Sodium Nitrate	A	A	A	A	A	B	B
Sodium Perborate	A	A	A	A	A	B	B
Sodium Peroxide	A	A	A	A	A	B	B
Sodium Phosphate	A	A	A	A	A	A	A
Sodium Silicate	A	A	A	A	A	A	A
Sodium Sulfate	A	A	A	A	A	A	A
Sodium Sulfide	A	A	A	A	A	A	A
Sodium Sulfite	A	A	A	A	A	A	A
Sodium Thiosulfate	A	A	A	A	A	B	A
Soybean Oil	A	B	A	C	A	A	B
Stannic Chloride	A	A	A	B	A	A	A
Steam-Under 300 °F	X	X	B	B	X	X	C
Steam-Over 300 °F	X	X	B	C	X	X	X
Stearic Acid	A	A	A	B	A	B	B

Rating Key: A-Recommended Little or no effect B-Minor to moderate effect C-Conditional - Varies from moderate to severe under different conditions X-Not Recommended Severe effect I Insufficient data to rate

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Stoddard Solvent	A	A	A	X	C	A	C
Styrene	C	C	B	X	X	X	X
Sucrose Solution	A	A	A	A	A	A	B
Sulfite Liquors	A	A	A	B	A	B	B
Sulfur	A	A	A	A	A	X	A
Sulfur Chloride	A	A	A	X	A	C	C
Sulfur Dioxide	A	A	A	B	A	X	C
Sulfur Hexafluoride	A	A	A	A	A	B	A
Sulfur Trioxide	A	I	A	B	A	X	X
Sulfuric Acid (20% Oleum)	A	X	A	X	A	X	X
Sulfuric Acid, Dilute	A	C	A	B	A	X	B
Sulfuric Acid, Conc.	A	X	A	X	A	X	X
Sulfurous Acid	A	X	A	B	B	B	B
Tannic Acid	A	A	A	A	A	A	A
Tar, Bituminous	A	A	A	X	A	B	C
Tartaric Acid	A	A	A	B	A	A	B
Terpineol	A	B	A	C	A	B	X
Tertiary Butyl Alcohol	B	X	A	B	B	B	B
Tertiary Butyl Catechol	A	X	A	B	A	X	B
Tertiary Butyl Mercaptan	B	X	A	X	B	X	X
Tetrabromamethane	C	X	A	X	C	X	X
Tetrabutyl Titanate	A	B	A	B	A	B	B
Tetrachloroethylene	C	B	A	X	C	C	X
Tetrahydrofuran	C	X	X	B	X	X	X
Tetralin	B	B	A	X	B	X	X
Thionyl Chloride	A	A	A	X	A	X	X
Titanium Tetrachloride	A	X	A	X	A	C	X
Toluene	C	B	A	X	X	C	X
Toluene Diisocyanate	C	C	B	B	C	X	X
Transformer Oil	A	A	A	X	C	A	B
Transmission Fluid A	A	A	A	X	C	A	B
Triacetin	A	X	X	A	A	B	B
Tributoxy Ethyl Phosphate	C	C	A	A	C	X	X
Tributyl Phosphate	C	C	X	A	X	X	X
Tributyl Mercaptan	C	C	A	X	C	X	X
Trichloroethylene	C	B	A	X	X	C	X

CHEMICAL	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
Trichloroethane	C	C	A	X	C	X	X
Trichloroacetic Acid	A	X	C	B	A	B	X
Tricresyl Phosphate	A	C	B	A	C	X	C
Triethanol Amine	A	X	X	B	B	C	A
Triethyl Aluminum	A	X	B	C	A	X	X
Triethyl Borane	A	X	A	C	A	X	X
Trinitrotoluene	A	I	B	X	C	X	B
Trioctyl Phosphate	C	X	B	A	C	X	X
Triaryl Phosphate	C	X	A	A	C	X	X
Tung Oil	A	C	A	C	C	A	B
Turbine Oil	A	A	A	X	C	B	X
Turpentine	B	A	A	X	C	A	X
Urea	A	A	A	A	A	A	A
UDMH	C	X	X	A	C	B	B
Varnish	A	A	A	X	C	B	X
Vegetable Oils	A	A	A	C	C	A	C
Versilube	A	A	A	A	C	A	A
Vinegar	A	X	A	A	A	B	B
Vinyl Acetate	A	A	A	C	X	A	A
Vinyl Chloride	B	B	A	X	X	X	X
Vinyl Halides	C	C	C	C	X	C	C
Wagner 21B Fluid	I	I	X	B	I	C	B
Water	A	B	A	A	A	A	A
Whiskey, Wines	A	B	A	A	A	A	A
White Pine Oil	C	A	A	X	C	B	X
White Oil	A	A	A	X	B	A	B
Xylene	X	A	A	X	X	X	X
Xylidene	C	X	X	X	X	C	X
Xylol	B	B	B	X	B	X	X
Zeolites	A	A	A	A	A	A	A
Zinc Acetate	A	X	X	A	A	B	B
Zinc Chloride	A	A	A	A	A	A	A
Zinc Oxide	A	A	A	A	A	A	A
Zinc Sulfate	A	A	A	A	A	A	A

Rating Key: A-Recommended Little or no effect B Minor to moderate effect C Conditional Varies from moderate to severe under different conditions X Not Recommended Severe effect I Insufficient data to rate

SUMMARY OF MATERIAL COMPATIBILITY RATINGS

	CPE	F.R. URETHANE	VITON	BUTYL	VINYL	NITRILE	NEOPRENE
A	306/61%	159/32%	328/65%	197/39%	222/44%	182/36%	156/31%
B	60/12%	67/13%	58/12%	113/22%	92/18%	92/18%	120/24%
C	81/16%	59/12%	17/ 3%	43/ 8%	81/16%	34/ 7%	47/ 9%
X	26/ 5%	184/36%	83/16%	151/30%	74/15%	197/39%	182/36%
I	32/ 6%	36/ 7%	19/ 4%	1/ 1%	36/ 7%	0/ 0%	0/ 0%
Total Chemicals	505	505	505	505	505	505	505

ILC Dover offers a complete line of chemical protective garments made from CPE, Flame Retardant Urethane and Viton. FOR FURTHER INFORMATION CONTACT:

CHEMICAL PROTECTION

The Chemturion

Material

All suits are crafted of 20 mil light blue Cloropel. Cloropel has a proven resistance to weathering, ultra-violet, and a host of chemical products.

Closures

Front - Outer extruded closure in conjunction with inner restraint zipper. Outer extruded closure made of Cloropel utilizes two (2) parallel sealing lips, providing an effective penetration barrier.

Hood/Visor

Each suit contains press-polished optical grade 40 mil vinyl in the visual area with replaceable polyester splash visors. Internal easement permits head movement for 180 degrees of vision.

Construction

Heat-sealed seams are designed to permit full mobility without excessive suit shifting. Suits incorporate molded wrist cuffs with mating neoprene wrist rings which are replaceable.

Sizes

One size to fit 5'4" to 6'4". Extra large available upon request.

Weight

Approximately four pounds.

Models Available

Number 12

For use with an external air source.

Number 13

For use with a wide range of self-contained breathing systems.

Number 84

Accommodates both external air sources and self-contained breathing systems.

Number 12 Airline/Egress

Accommodates both external air sources and airline/egress systems.

No attempt has been made to dictate choice of gloves and outer boots for use with Chemturion suits. Your personal evaluation, predicated by on-site use, is completely compatible with the system offered.

Model Number 1904 Cool Vest

The portable vest contains a battery-driven pump which circulates chilled water throughout a series of passages within the vest. The vest holds an ample supply of ice and water. No external connections are necessary. Aids in maintaining worker comfort and safety.

NATIONAL SURVEY OF HAZMAT COURSES

Steve Hausotter
Contra Costa County Consolidated Fire District
Pleasant Hill, CA 94523

I. Introduction

During the past year, the Association of Bay Area Governments has conducted an extensive project to develop and install in the San Francisco Bay Area, and throughout California, a comprehensive, complete hazardous materials incident response training system. Using an expert committee of personnel from over 20 local, state and federal agencies, existing training programs from throughout the country were identified and examined to establish the current state of development in training. Although the work of the hazardous materials training committee is not yet completed, valuable information has been collected about courses in the United States. This information has been compiled into a directory titled "National Directory of Hazardous Materials Training Courses". It should prove valuable to anyone searching for a course on a particular topic and provide data from which an initial selection may be made.

The directory includes a discussion of the current status of public and private sector hazardous material training. Of particular import is the assessment of the deficiencies in current training which indicate the pitfalls to avoid, which will be addressed later in this topic.

The directory contains an actual listing of training courses available at the close of 1984. With the exception of specialized materials developed for use within an industry, many courses trace their origins to a handful of offerings from the U.S. EPA, Texas A&M University and the National Fire Academy. Usually such courses have been modified to suit a specific audience or geographical area.

II. Summary of Problems Identified in Current Training Programs:

1. TRAINING COURSES ARE OFTEN INACCESSIBLE.

   Although there appears to be an abundance of training programs nationally, local personnel are often prevented from participating in them due to a lack of resources--<u>time and money</u>.

2. THE QUALITY OF TRAINING COURSES PRESENTLY AVAILABLE IS EXTREMELY VARIABLE.

The one- or two-session format often used is an attempt to address all pertinent issues and problems in a convenient amount of time; unfortunately, such courses ultimately provide general knowledge rather than specific skills.

3. THERE ARE NO GENERALLY ACCEPTED STANDARDS OR CRITERIA FOR HAZARDOUS MATERIALS TRAINING REQUIREMENTS.

Since there has been no systematic analysis of the knowledge and skills that various prevention and response personnel should possess, it is left to the individual agency to determine its employees' needs and fill them, resulting in wide variations in preparedness. In addition, the lack of standards makes it difficult for course developers to provide relevant training and it complicates the consumer's ability to choose among courses.

4. THERE IS NEITHER A CLEARINGHOUSE FOR INFORMATION ON HAZARDOUS MATERIALS TRAINING PROGRAMS, NOR A FOCAL POINT FOR PROVIDING SUCH TRAINING.

In order for agencies to participate in training programs, they must first know of their existence. At present there is no central place to go for information on available programs, causing some needs to go unmet unnecessarily. The fact that there is no focal point for training often leaves the consumer at the mercy of the trainer's standards of quality.

5. AN INSUFFICIENT NUMBER OF PREVENTION AND RESPONSE PERSONNEL IN PUBLIC AGENCIES ARE ADEQUATELY TRAINED TO DEAL WITH HAZARDOUS MATERIALS.

Although there are some exemplary training programs in certain local jurisdictions, this is not the case for most regions as a whole. For example, two-thirds of the personnel in fire departments surveyed (small, medium and large) had not been trained in areas such as spill containment, risk assessment, properties of chemicals and pertinent regulations. Even those who had received such training gave it an overall rating of "inadequate".

6. TRAINING RECEIVED BY PRIVATE COMPANIES HAS BEEN DIFFCULT TO ASSESS, BUT APPEARS TO BE WIDELY VARIABLE IN BOTH QUANTITY AND QUALITY.

If hazardous materials prevention/response training is seen as a priority by management and if resources (time, money,

staff) are available to provide such training, the company may be well trained to deal with the hazardous materials they use. Subjectively, there are probably many companies for which hazardous materials training is a high priority. However, without an independent set of training standards, it is difficult to make definitive statements in this area. Further work is required in order to properly assess the extent of training needs for private industry.

III. First Responder Training Topics

Many first responder training courses are billed as complete packages providing all necessary information. This is not true for advanced level training, where most providers concede that a complete curriculum is not yet available. How true is the claim at the first responder level? The answer lies in two factors--the definition of first responder and the duties assigned to that person by his/her employer.

The ABAG Hazardous Materials Training Committee has adopted a working definition of first responders. First responders are considered all personnel of public agencies who may first respond at the scene of a chemical spill. First responders have limited duties which include scene assessment, notification of proper authorities, isolating the scene, and assisting, as needed, the chemical response team or the incident commander/scene manager. First responders are not expected to have detailed knowledge, skills, or equipment to contain or clean-up spilled communication, first aid, etc.

The following list contains the topics that the Training Committee felt should be taught to <u>all</u> first responders as part of a complete training package. The amount of information presented under each topic would vary depending upon the functions of the agency, but all topics should be covered. Also, visual aids and problem solving exercises are important additions to a complete course.

The following topics would be covered in a complete first responders course:

HAZARD IDENTIFICATION
- Placarding system
- Bill of lading/manifest
- Recognition of potential hazards
- Resources for information

HEALTH AND ENVIRONMENTAL ISSUES
- Routes of contamination
- Approach procedures
- Supplemental first aid
- Protective equipment
- Impact to air, land and water

NOTIFICATION
Agency roles and responsibilities
Data requirements
Protocols

INCIDENT MANAGEMENT
Own agency role and responsibilities
Other agencies roles and responsibilities
Introduction to contingency planning

INVESTIGATION
Sampling techniques
Liability/cost recovery informational needs

CONTAINMENT AND CONTROL
Containment/control means and methodology
Coordination of containment/control activities
Knowledge of command procedures

FORMAT
Modular
Time/equipment requirements

IV. Advanced Level Training

California law has separated scene management from advanced level response team duties. For incidents on highways or city streets, scene management is by statute the responsibility of the primary law enforcement agency having primary traffic investigative authority where the incident occurs, notably the Highway Patrol, Sheriffs departments or city police. Yet the historical development of skills for containing a spill, securing a scene, rescuing victims, and in some cases clean-up, has taken place within the fire departments of the state. In general, and perhaps rightly so, police agencies have not accepted a technical role in hazardous materials incidents beyond scene management.

Because of this situation, the Training Committee has given close attention to the relative roles and responsibilities of scene managers/incident commanders and response team members. In developing a comprehensive curriculum for advanced level training, one of the first steps taken was to identify current responsibilities of scene managers and response teams. Information was culled from numerous official job descriptions and local spill plans and a listing of responsibilities was prepared. This listing will certainly evolve with time but now provides a minimal listing of the many types of training topics that should be covered at the advanced level.

Table 1 presents the listing of responsiblities/skills to be taught at the advanced level. The topics are identified by whether they should be taught at an introductory level or as a complete course to response team members and scene managers.

TABLE 1. JOB FUNCTIONS OF ADVANCED LEVEL RESPONDERS

	Training Requirements			
	Scene Manager		Response Team	
Function	Introductory	Complete	Introductory	Complete
Training of others				X
Preplanning, site specific	X			X
Prepare reports		X		X
Maintain records		X		X
Media contact		X		
Occupational exposures, incidents		X		X
Matl. identification+ min. chem.	X			X
Hazard identification	X			X
Collect samples				X
Analyze samples, mobile lab.				X
Assess health risks	X			X
Monitor exposure	X			
Notification		X	X	
Scene management		X	X	
Command organization				
Establish communication		X		X
Identify resources		X		X
Evacuation		X	X	
Rescue victims				X
First aid, chem. exp.				X
Stabilize scene	X			X
Operate special equipment				X
Maintain special equipment				X
Wear protective clothing				X
Containment				X
Decontaminate				X
Supervise cleanup		X		X
Authorize 3rd party cleanup		X		
Request funding aid		X		
Financial responsibility		X		
Weather data/gases	X			X
Isolate scene		X		X
Radiological response	X			X

V. Features Desired in a Training System:

1. Courses should be locally accessible (both geographically and economically) on an ongoing basis;

2. Curricula should be developed with input from the target group(s) for whom the training is intended;

3. Special circumstances and hazardous materials characteristics of the region should be identified and incorporated into local training courses;

4. Any advisory board, composed of multidisciplinary representatives from public and private agencies who handle hazardous materials, should provide guidance and direction for the training system; a primary role for this group could be to obtain agreement upon and standardization of training required to perform specific jobs, as well as standardization of curricula for each level of training.

5. Courses should emphasize simulation and hands-on experience, particularly for training emergency response team members and those supervising them.

6. Participants should be evaluated against performance standards before "graduating"--the development of a certification system could help ensure this.

VI. Features Desired In Hazardous Materials Courses:

In selecting a hazardous materials course, primary concern should be focused upon the needs of the agency and duties of the students. Due to the unpredictable nature of hazardous material incidents, any responder with limited duties should nonetheless be trained in other responsibilities, procedures and skills, even if only at an introductory level.

There have been many courses developed to cover various aspects of hazardous materials incident response. As noted earlier, some originate from the same basic stock of EPA, National Fire Academy, and Texas A & M University courses and were altered to meet the needs of the provider or a class of students. Other courses originated as one-day workshops that were financially successful or were praised for their content.

It is a difficult task to select a course that will meet the needs of a group of students. Trial and error is one system that will eventually uncover the proper course and should impart some knowledge along the way. However, trial and error can be costly and time consuming.

In reviewing courses for presentation in Northern California, the ABAG Training Committee identified several characteristics that, while they do not guarantee an excellent course, are common among the better, well-prepared and thought-out courses. These include:

1. A mixed format. Material presented in a variety of modes during a single class helps maintain student alertness and interest. The various modes that can be integrated into one course include slide, overhead transparencies, lecture, videotape, student manual, movies and simulations.

2. Student handouts. A well-prepared course should include a manual or compiled handouts. It is important for students to retain basic reference material after completion of the course.

3. Reinforced learning modes. For optimum retention of knowledge by the student, multiple pathways to the brain can be utilized. This means visual aids that reinforce the lecturer's words, that reinforce the student manual that is also reinforced by student's notes and exercises.

4. Student objectives. A quality training course will result in measurable improvement in skills or performance by the student. The best training courses are developed around a stated group of student objectives.

5. Student feedback. Difficulties can arise when an instructor does not precisely meet student objectives in his/her material or when the pace of instruction does not match the learning abilities or previous experience level of the students. The better courses will provide frequent opportunities for the instructor to assess what the students have learned and adjust the lecture if necessary.

6. Detailed instructor guide. A number of courses with excellent material have received mediocre to poor reviews. Also, the same course delivered by two different instructors has been perceived as two vastly different courses. For consistent quality and presentation of material, a detailed instructor's manual and/or guide helps assure that students taking the class at different times will receive the same material.

When inquiring about courses, ask about these key points. Also, obtain references from others who have taken the courses. The most accurate judgments may come from those whose skills levels exceed the material of the course being considered.

SPILL RESPONSE: TRAINING IS ESSENTIAL

by

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INTRODUCTION

Major spills are fought using well established methods. The Easter Sunday spill in Denver is classic in description, response, and coverage. Smaller spills, however, of the type we frequently see in laboratories and on process lines, seldom cause the evacuation of thousands of people and do not, therefore, generate the interest which results in investigations, recommendations, and (possibly) actions. These smaller spills, however, do effect the lives of those directly involved. Smaller spills are just as dangerous as large spills, usually for different reasons. Prevention of and preparation for for these smaller spills is the object of our "Hands On Approach" to spill response training.

Ideally, the concerned supervisor could go to some standard references and obtain information which could be used to develop plans for fighting small spills. Unfortunately, this is not the case. "Prudent Practices for Handling Hazardous Chemicals in

Laboratories" (1) devotes just over three pages to the subject of spills; "Safety in Working With Chemicals" (2) has just over 2 pages; Bretherick's "Hazards in the Chemical Laboratory" (3) has less than 1 page, and this is devoted mainly to disposal; finally, "Hazardous Materials Spills Handbook" (4) has an entire chapter devoted to spill cleanup, but the focus is primarily large spills.

We will briefly review the Easter Sunday Spill to develop the information that those involved in a small spill should have. We will then present a training format that formalizes what we have learned from large spills for the users of chemicals who are potentially subject to smaller spills. Finally, by reviewing some actual training sessions,we will illustrate actual problems we have encountered and the lessons we have learned.

THE DENVER SPILL

Given that we all define a spill as a "chemical out of control", the Denver incident is ideal to learn how a proper response works. The spill occurred in the Denver railroad yards and released a toxic plume over a populated area (5). The material spilled was concentrated nitric acid and the fumes were generated from the attack of the rails by the acid. Over 5,000 people were evacuated because of the plume. The spill was initially fought by using snowblowers to spray the contaminated area with soda ash. This was exceedingly effective and the public response was very positive. The fast, effective action on

the part of the railroad and by public agencies prevented panic and limited injury and property damage. This spill was thoroughly investigated by many interested agencies. As we all know, this spill was by no means the only one of its type in the US. Table 1 (6) reports a recent sampling of major spills. However, each of these incidents was large. Each caused sufficient disruption of daily life that the press was alerted. Each was ultimately resolved.

What lessons did we learn from the Denver spill? Clearly, the railroad was prepared. They had methods for identifying the material, protecting life and property, and fighting the spill. They mobilized a trained response team, composed of experts, who worked in conjunction with local authorities. Ultimately, they also supplied the financial resources to completely resolve the issue. Are these mechanisms in place in laboratories, process plants, or warehouses? Sadly, the answer is "No". This review of the Denver Spill should provide guidance to complete the Spill Response Worksheet, illustrated in Figure 1.

When hazardous waste is involved, training is required under 262.34(5)(b) of RCRA. In addition, RCRA requires a Preparedness and Prevention Plan (262 Subpart C) and a Contingency Plan and Emergency Procedures (262 Subpart D). OSHA has a similar training requirement, with respect to hazardous material handling, but does not require emergency preplanning. Many sites that are subject to small spills are not aware of these requirements. Many users of hazardous materials fail to realize

TABLE 1

SUMMARY OF RECENT ACID SPILLS

In September, 1982, hundreds of people were evacuated from Hanford,CA., when a corrosive acid ate through the bottom of a tanker truck. No injuries were reported.

Three persons were killed in Gulfport, MI., in June,1982, when a mixture that included nitric acid ignited at a plastics manufacturing plant. Sixty-five persons were injured.

A mile long toxic cloud forced the evacuation of 400 persons in Biggsville,IL., in May, 1983, after the acid leaked from a railroad car. One person was injured.

In Nitro, Quebec, April, 1983, a nitric acid tank exploded, forcing the evacuation of about 1,000 persons.

In January, 1982, a cloud of chlorosulfonic acid resulting from a leak in a railroad car, forced the evacuation of about 2,500 people in Haleyville, AL.

A cloud of hydrochloric acid from a ruptured industrial pip forced the evacuation of 1,300 people near Moses Lake, WA, last May.

Another cloud of HCL leaked from a tanker near Bryant, AR., last July. Six hundred people were evacuated and three truck drivers were treated for HCl inhalation.

Hundreds were evacuated, including some hospital patients, last July in South Charleston, WV.,following an HCl leak from a railroad tank car.

And, in Niagra Falls, NY, in November, 1982, chlorine gas from an industrial plant blew over a college football game resulting in 76 persons requiring medical treatment.

(Extracted from the Denver Post, April, 1983)

CHEMICAL SPILL WORKSHOP

DO NOT WRITE ON THIS PAGE UNTIL INSTRUCTED TO DO SO

Directions: Work together in small groups for 15 minutes. Discuss the various steps necessary for properly fighting a 1 gallon spill of a flammable, corrosive chemical in an occupied building. Use the steps suggested below as a guide, but feel free to add to or delete from the list. In the space below, list, based on your small group discussion, the steps, in the order you would follow them, you suggest to resolve the spill.

YOUR SUGGESTED PROCEDURE

POSSIBLE STEPS FOR FIGHTING A SPILL

DEVELOP A PLAN OF ACTION
DETERMINE THE CHEMICAL HAZARDS
DIKE THE SPILL, ABSORB ALL FREE LIQUID
SALVAGE ANY EQUIPMENT, etc., AS APPROPRIATE
TREAT ALL SPILL RESIDUE AND REFUSE AS HAZARDOUS WASTE
DECONTAMINATE AREA (use water for final rinse)
CLEAR THE AFFECTED AREA
CLEAN UP & CONTAINERIZE BULK SPILL RESIDUE
DON APPROPRIATE PERSONAL PROTECTIVE EQUIPMENT, USE ADEQUATE CONTAINMENT MATERIALS
ALL INVOLVED PERSONNEL MUST SHOWER OUT AS SOON AS PRACTICAL.

add more steps if necessary

FIGURE 1:

A worksheet designed for use in the Hazardous Chemical Spill Workshop. Use this to help preplan the proper approach to spill management. (Reprinted with permission of the J.T. Baker Chewmical Company, Office of Training Services.)

that when a hazardous material is spilled, the residue becomes a hazardous waste. Small spills are fought using primitive methods, with whatever material is handy. We can all remember the school laboratory with the bottle of soda ash for acid spills, and paper towels for everything else.

Thirty percent of all laboratory injuries are spill related. Of these, the majority occur during clean up. The usual scenario is that someone breaks a bottle, of toluene, for example and calls for assistance from a coworker for the clean up. Frequently nothing much visible happens; sometimes tragedy occurs. Lack of knowledge is the cause.

SPILL RESPONSE: TRAINING IS ESSENTIAL

Training is the answer. Training should address prevention, preparedness, and emergency response. It should be didactic, practical, and applied. The classroom components of training are:

CAUSES OF SPILLS

PRINCIPLES OF SPILL CONTROL

SPILL CONTROL MEDIA

CHEMICAL HAZARDS and SAFETY

PERSONAL PROTECTIVE EQUIPMENT

HAZARDOUS WASTE MANAGEMENT

The practical aspects of training are:

PERSONAL PROTECTIVE EQUIPMENT USE

FIRE FIGHTING METHODS

SPILL FIGHTING PROCEDURES FOR:

ACIDS

CAUSTICS

FLAMMABLES

CHEMICALS SPECIFIC TO SITE
e.g. pesticides, reactives, toxics

LEAKER MANAGEMENT

CHEMICAL WASTE DISPOSAL

DECONTAMINATION

These requirements have been incorporated into a total involvement training program. The program and its results can now be reviewed. We will review the training to examine the problems that have developed and the lessons we have learned.

The classroom material is straight-forward and practical. Because we are frequently confronted with workers of limited chemistry background who are charged with the responsibility of handling hazardous materials and cleaning up spills, we are careful to keep the amount of chemistry to a minimum. Hydrochloric acid, for example is referred to variously by name and as muriatic acid and swimming pool acid. Similarly, common names are used in conjunction with other commercial products, as appropriate. Slides, video tapes, and lecture-discussion are interspersed to maintain a positive learning atmosphere. Actual incidents from the site in question are used to emphasize points and reinforce learning.

The hands on training occurs on the company property, out-

doors. The training site is selected by the company and reviewed by the instructors. Because we are actually spilling chemicals on the site, it must be selected carefully. For example, hydrocarbon spills, such as pentane, will dissolve new asphalt. Acids spills, on the other hand, will etch concrete. It is important that personal protective equipment (PPE) be used, properly. The level of PPE depends upon the procedures in place on site. At a very minimum, workers must have full body splash protection, hand, face, and eye protection, and respiratory protection. The instructors also use this minimum level of protection.

Because the danger of fire is high, even during training, fire extinguisher training is essential. While pan fires of flammable liquids are useful, realistic training is best obtained from actual spills resulting from broken containers. Typically, a 1 gallon bottle of pentane (or similar solvent) is broken and the material is ignited. Permission of the local fire department for this type exercise is needed. Pairs of workers then fight the fire. This type of hands-on, realistic training teaches respect for the intensity of a solvent fire more than trying to fight a small pentane fire. Sufficient fire equipment must be available for fire fighting training, protection of the training site during the day, and normal, 100% protection of the entire facility.

Chemical spill training uses whatever media the company generally employs. However, if the media is inherently unsafe, then a more appropriate media must be on hand. For example, one

facility had a motor pool worker attending the workshop. He commented that spilled battery acid was cleaned up with saw dust. He admitted that they had occasional fires in their trash dumpster, after such spills. We demonstrated the cause of such fires, and then used a more appropriate media for cleaning up an actual spill of battery acid.

Decontamination of personnel must be stressed. Because everyone is wearing adequate PPE, we tend to forget that outerware may be contaminated during a cleanup exercise. In one case, the site safety officer responded to a worker's heat stress by attempting to remove him from a "moon suit" prior to decontamination. Since the Safety Officer was not protected, our instructor correctly assumed he was contaminated with hydrofluoric acid and turned the 1-1/2 inch water line on him. He, and his staff, learned an important lesson from this quick response on the part of the instructor.

Waste disposal, and ultimate site decontamination, must also be addressed. Companies which obtain this level of training already are disposing of hazardous waste within the dictates of RCRA. We usually place all spill residue in a salvage drum and manage it as a hazardous waste. Usually the contents are classified as an EPA corrosive waste and assigned an EPA number D002. For shipping of the salvage drum, either the DOT proper shipping name "Corrosive solid, n.o.s." or "Flammable solid, corrosive,n.o.s." is selected. At the end of the training

session, the area is thoroughly cleared and ultimately hosed down with large quantities of water.

Worker stress in spill situations is a serious detriment to proper response. We cannot expect employees to respond to a hazardous material spill with no prior experience. Spill media react differently with different chemicals. Fumes, smoke, and injuries lead to high anxiety and potential panic. Dealing with this stress is an important part of the training program.

This training program has proved effective. Followup interviews, conducted approximately 6 months after the training, indicate that the companies are more aware of the potential for injury, that workers are more prone to prevent spills, and that spill management teams are highly responsive to personal protection and proper procedures.

CONCLUDING COMMENT

Realistic spill training involves using the type chemicals employed by the site. This requires preplanning and communication. Adequate material must be available. The site must be carefully selected and prepared. Sufficient water must be available for emergencies, cleanup and decontamination.

Despite all precautions, spills will occur. Whether the cause is a broken container or a ruptured transfer line, the material must be managed in a safe and proper fashion. The realistic training prepares your workers for accidents and helps reduce injury and loss.

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CERTIFICATION for HAZARDOUS MATERIALS TECHNICIANS

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BACKGROUND

Hazardous waste and materials management is a relatively new, rapidly evolving field in which education and experience are often measured in "trial by fire" increments as opposed to formal diplomas, or via predictable career paths. Few university curricula or vocational technical programs are found which will prepare the very people upon whose shoulders rest the critical responsibility for accident prevention, risk reduction and emergency response: hazardous materials handlers, technicians, operators, supervisors, transporters, and incident responders. Certified institutional training is demanded in light of the chronic recurrence of spills, environmental releases and chemical catastrophes which have occupied so much media attention over the past decade.

Clearly, a national initiative for quality training and certification is needed and requires the talents of professionals from all disciplines concerned with proper hazardous materials

response. Two organizations possessing a wealth of experience and a remarkable track record have taken that initiative.

IECA FOUNDERS

The Institute for Environmental Career Advancement, a joint creation of the Spill Control Association of America (SCAA) and the Environmental Hazards Management Institute (EHMI), has launched an effort through which public and private entities who are truly concerned with the safe cradle to grave handling of hazardous materials can determine an individual´s competence in and knowledge of the hazardous waste and materials disciplines.

One would be hard pressed to find two better suited organizational founders, for both the SCAA and EHMI have been national leaders in turning the hazardous waste and materials "issue" into a hazardous waste and materials "profession". They have done so by providing comprehensive, practical training programs and simulations for industry, government personnel, first-line responders and firms which specialize in the investigation, control and remediation of uncontrolled chemical sites. They have organized and disseminated much-

needed, quality information to the many and diverse actors who together, constitute a unique profession.

OBJECTIVES

Due to the extraordinary increases in the use of criminal prosecution and the enormous personal and organizational liabilities, there is a growing urgency among private sector firms and the governmental agencies to require hazardous materials certification of both existing and potential employees.

Therefore, IECA will:

1. Evaluate an indivual´s blend of education, experience and relevant training in the field of hazardous materials and waste handling.
2. Certify individuals who, by virtue of their blend of education, experience and training, will enhance the profession by their demonstrative ability to prevent accidents, reduce risk and/or to competently respond to chemical emergency incidents.

3. Stimulate the continuing education and career advancement of those charged with the critical responsibility for safe handling, transportation, supervision of and/or response to hazardous materials.

4. Identify and evaluate offerors of hazardous waste and materials training programs in order to increase, or better describe, the options facing those mandated to provide or attend such courses.

5. Identify those sites across the nation which will upgrade the levels of certification offered by providing hands-on training for - and not simply written examinations of - an individual´s professional capability.

DEGREES OF CERTIFICATION

The initial evaluation of an individual´s credentials and/or the successful completion of a competency exam will determine a level of certification on a foundational basis. That is, it is anticipated that there will be varying degrees of certification in varying aspects of the multi-disciplinary field of hazardous materials handling.

For those eager to upgrade their certified level of "response" capability, for example, there will be training for and certification of, capability ranging from Hazard Assessment to Personal Protective Equipment and Respirators to Decontamination. Hazardous materials "technicians" may seek certification upgrades based upon their continuing training and demonstative expertise in such areas as Contingency Planning, disposal and recycling options; transportation liabilities, requirements, and notification procedures; health and safety planning; crisis communications, etc.

In short, an individual may select those professional categories and levels of certification most appropriate for his/her current job description or career plans.

<u>THE CERTIFICATION PROCESS</u>

Those wishing to apply for foundational certification as a Hazardous Materials Technician must first complete the Institute for Environmental Career Advancement Application form and submit it to the address shown below. A determination will then be made by the Institute´s

Board as to whether a competency exam is necessary.

IECA has established several examination and training sites around the country and expects to offer additonal, accessible locations in the near future. For further information, you may call or write:

Institute for Environmental Career Advancement
1920 N. Street NW
#150
Washington, DC 20036
202/296-5719

THE PSYCHOLOGICAL ASPECTS OF PERSONNEL CONTAMINATION*

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INTRODUCTION

This paper discusses some of the major emotional considerations involved in the treatment of people who have been contaminated with potentially hazardous materials. Although the principal focus of this paper is the treatment of people trained to work with these materials, an attempt will also be made to extend these methods to people having little or no knowledge of such matters.

In addition to the anatomic and physiological effects, accidents always result in emotional trauma. When the accident involves radioactive or other potentially toxic, carcinogenic, or mutagenic materials, there is a possibility of enhanced emotional stress due to the mystique surrounding these substances.

The remainder of this paper will address the treatment of people contaminated with radioactive materials. The examples cited are related primarily to personnel who have experienced low-level plutonium contamination at the Lawrence Livermore National Laboratory as well as an extreme case of a person who was exposed to a large quantity of americium contamination at the Hanford facilities in Richland, Washington. Since the techniques discussed have proven effective in dealing with workers exposed to these highly-toxic substances, the same basic principles can be readily applied when working with people contaminated with any material perceived to be hazardous.

ORIENT AND TRAIN BEFORE THE ACCIDENT

People who routinely work with radioactive materials will usually receive annual training in the nature and hazards of those materials, and should be generally well-informed about radiation effects. Such orientation should include a description of the treatment to be administered in the event of contamination. When these workers become contaminated, they tend to be more cooperative during decontamination,

*Work performed under the auspices of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

and are able to make more rational judgments as they participate in their treatment.

Most of the Lawrence Livermore National Laboratory's plutonium workers, for example, are well prepared and informed in this regard. Many have studied the biological effects of radiation and the treatment of contaminated personnel during their years of employment in radiation work. Observation of their perceptions and reactions when they become contaminated reinforce the importance of training programs that emphasize these topics.

It has been observed that these well-prepared workers tend to respond rationally and cooperatively when they have become contaminated. Their understanding of the minimal hazard associated with superficial skin contamination, and the ease with which such contamination is typically removed, tend to minimize their initial concerns.

On the other hand, people who only occasionally work in plutonium-handling facilities tend to be less prepared to deal with personal contamination and decontamination. Custodians, security officers, and members of the crafts are required to have only minimal training in the hazards of plutonium. An annual, one-hour orientation may have little effect on the misconceptions developed over an entire lifetime.

The responses of these people vary considerably when they are confronted with plutonium contamination of their bodies or clothing. Some have exhibited levels of calm inconsistent with their apparent level of knowledge. Many others have openly expressed their fears. In a few cases, irrational actions have been observed.

In the initial assessment of the psychological impact of a contamination accident, determination of the nature and extent of the worker's pre-accident knowledge and experience is extremely important in the planning of care and treatment.

AVOID SECRECY

In order to limit the development of further anxiety, it is important to establish trust and rapport between the contaminated worker and the treatment team. In promoting this trust, it is important to establish a routine so that procedures can progress on schedule and uncertainty can be minimized. Above all, the worker must be shown that concern for his or her well-being is the highest priority.

A copy of the Laboratory's established personnel decontamination procedures is posted on the wall of the decontamination room in the plutonium facility. This serves two purposes. First, since personnel

contamination is an infrequent occurrence in this facility, it reminds the decontamination team of the tested, systematic techniques that are to be used. Second, it provides the person being decontaminated with an assurance that the techniques being used were well thought out in advance, and not just random attempts to find a solution to the problem.

It has also been found to be beneficial to discuss each step of the procedure with the contaminated worker prior to its initiation. This discussion should include both the details of what is to be done as well as the possible positive and negative effects of each action.

It is imperative that the contaminated worker be involved in the decision-making process during decontamination. Although the treatment team physician and staff have the expertise to decide on an appropriate course of action, the affected worker needs to be consulted as decisions are made. This minimizes the risk of the worker feeling like an inanimate object.

It has been observed that this can be an extremely critical time emotionally for the contaminated worker. Many have commented on the concern, or lack of concern, shown for them during the initial stages of decontamination. In dealing with the technical problems associated with decontamination, the human being must not be neglected.

MINIMIZE ISOLATION

Depending upon the extent of contamination involved, a contaminated worker may need to be isolated from other workers during the initial steps of decontamination. Prolonged isolation can, however, have an adverse emotional effect on the worker. As soon as it is safe to do so, the worker should be allowed to come into contact with others.

Personnel decontamination is typically conducted in an isolated room or area in order to minimize the spread of contamination. This often leads the contaminated worker to conclude that he or she is in great jeopardy as well as being a hazard to others. Allowing the worker to come into contact with co-workers can help dispel undue concerns regarding the hazards associated with being contaminated.

These co-workers should be briefed prior to this initial contact. For them to be a positive influence on their co-worker they must not ridicule or condemn the actions leading to the worker being contaminated. Even when done in jest, this has proven to be extremely detrimental to the attitude of the person who was contaminated.

PREPARE THE FAMILY

Once decontamination has been partially or totally completed, the worker's relationship to his family becomes important. The emotional benefits derived from being with family members after a contamination accident can be very important. If, however, either the family or the worker have unanswered fears associated with the accident, the overall effect can be negative.

The family must be educated as rapidly as possible after the accident. This education should include information regarding the impact of the exposure on the worker's health and well-being. It must also address the hazards, if any, that they might incur as they come into contact with the worker.

This last concern becomes extremely important if, after routine decontamination is completed, some small amount of the contaminant remains below the surface of the skin. The worker may be required to wear a covering over the affected area until the material has been released from the pores of the skin. If this is the case, discussions of potential community reactions and embarrassing situations should be undertaken with the members of the family. They can form the basis for reply to questions about the accident when they are confronted with community curiosity.

If the worker is experienced and knowledgeable, and if no residual contamination remains, he or she may be able to conduct the briefing of the family. If at all possible, a member of the treatment team should be available. In either case, the worker should decide what is in the best interests of the family.

FOLLOWUP AFTER DECONTAMINATION

The full emotional impact of the contamination accident may not be realized for hours, days, or even weeks after the fact. Once decontamination of a worker has been completed, insure that there are no lingering concerns or unanswered questions. The worker should be given a complete evaluation of the health implications of the contamination accident based on all analyses performed during and after the decontamination process.

CONCLUSIONS

Several psychological principles that have emerged from the treatment of radioactively-contaminated workers may be summarized as follows:

(a) Provide pre-accident training for all radiation workers, acquainting them with the kinds of exposures they might receive and the kinds of treatment that might be appropriate following such exposures.

(b) Avoid secrets. Share all information with the person who has been contaminated. Involve the worker in all medical decisions.

(c) As rapidly as possible following a contamination accident, bring the worker into contact with others.

(d) Recognize the emotions of the family and the family's fears and trauma. Educate the family as rapidly as possible to a full understanding of the accident and its implications.

(e) Do not desert the worker after decontamination has been completed. Help the worker keep concerns in perspective.

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HAZARDOUS WASTE

PROCESSING AND DISPOSAL

SUPERCRITICAL WASTE DESTRUCTION OF AQUEOUS WASTES

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Abstract

For aqueous wastes containing 1 to 20 wt% organics, supercritical water oxidation is less costly than controlled incineration or activated carbon treatment and far more efficient than wet oxidation. Above the critical temperature (374°C) and pressure (218 atm) of water, organic materials and gases are completely miscible with water. In supercritical water oxidation, organics, air and water are brought together in a mixture at 250 atm and temperatures above 400°C. Organic oxidation is initiated spontaneously at these conditions. The heat of combustion is released within the fluid and results in a rise in temperature to 600-650°C. Under these conditions, organics are destroyed rapidly with efficiencies in excess of 99.999%. Heteroatoms are oxidized to acids, which can be precipitated out as salts by adding a base to the feed. Examples are given for process configurations to destroy aqueous wastes with 10 and 2 wt% organics. Disposal costs are given as functions of waste throughput.

Introduction

Aqueous wastes containing organic materials represent a major fraction of the total toxic and hazardous waste generated in the U.S. The predominant treatment methods have been deep-well injection and lagooning (including solar evaporation). There are technical and economic issues that limit the applicability of each of these methods. For example, surface evaporation has been used extensively in California and is believed to be a significant factor in an already difficult air pollution problem. Deep-well injection, which has been used extensively in the Gulf Coast region, cannot be used indiscriminantly with wastes containing sizable concentrations of organics because <u>in situ</u> precipitation of solids can cause plugging of the porous rock formation. Where appropriate, these disposal techniques usually represent the lowest cost alternatives. However, they are available only in certain geographic regions. Transporting aqueous wastes from other locations can become the predominant cost and, not unusually, so high as to be prohibitive.

Alternative Methods of Destruction

The land-based disposal practices do not address ultimate destruction of the toxic components of the waste; consequently, there is increasing public concern with continued reliance on these techniques. Destruction methods, which usually cost an order of magnitude more than disposal methods, are based on oxidation of the organic content. For aqueous wastes, destruction methods include activated carbon treatment (with oxidative regeneration), incineration, wet oxidation and supercritical water oxidation.

For very dilute aqueous wastes (e.g., below 1% organic), activated carbon treatment is a viable alternative. Organics are first desorbed and then oxidized during regeneration of the carbon. After-burners are used to destroy vapors that may result from partial oxidation during regeneration. The major cost of carbon treatment is the cost of regenerating the carbon. The carbon loading, in turn, is directly proportional to the concentration of organic contaminant. For example, if an aqueous waste contains 1 wt% organic and if the contaminant content of spent carbon is .05 lb per lb carbon, then 1.6 lb of carbon is required per gallon of waste. If one pays $.20 per lb for regenerated carbon, then the carbon cost alone is $.32 per gallon for the waste containing 1 wt% organic. Since the cost per gallon is nearly proportional to the organic content, carbon treatment is usually not considered for wastes containing more than 1% organic.

Incineration, on the other hand, is usually restricted for economic reasons to relatively concentrated aqueous wastes. To attain high destruction efficiencies in treating toxic waste, incineration is conducted at high temperature (900-1100°C) with relatively long residence time (e.g.,2 sec). With aqueous wastes, the heat required to bring the water component of the waste to these severe conditions is substantial. If the waste contains 25% organic or more, there is sufficient heating value in the waste to sustain the process. With decreasing organic content, the supplemental fuel required to satisfy the energy balance becomes a major cost. For example, off-site costs of incinerating dilute aqueous wastes can range from $.50 to 1.50 per gallon; on-site costs above $.25 per gallon are not uncommon. Thus, controlled incineration of aqueous wastes with less than 20% organic is only considered in extenuating circumstances.

In the range of concentrations of 1 to 20% organic, wet oxidation and supercritical water oxidation are far less costly than controlled incineration or activated carbon treatment. In wet oxidation of hazardous wastes, organics are oxidized in the aqueous phase at temperatures in the range of 150 to 300°C and under pressures of 100 to 150 atm (1). In practice, residence times of 0.5 to 2 hr are required for removal of 50 to 95% of the initial COD. The residual organics are primarily innocuous aliphatic acids, which are by-products of oxidation of more complex molecules, and which are oxidized very slowly under wet oxidation conditions. Destruction of toxic organic chemicals (e.g., chlorophenols, nitrotoluenes) can be as high as 99.9%, but many materials are more resistant (e.g., chlorobenzenes and PCB's).

Although wet oxidation is more energy-efficient than incineration, the process suffers from a number of limitations. Under the conditions in which air and aqueous waste are mixed, the solubility of oxygen in water is considerably less than that required for complete oxidation. Thus a two-phase

mixture is present in the reactor. The reactor is an expensive item because it must operate at high temperature and high pressure with a relatively large volume to provide necessary residence time. Because the oxidation is not complete, the off-gas from the process can contain appreciable concentrations of volatile organics and may require additional treatment before release to the atmosphere.

Supercritical Water Oxidation

The MODAR process for supercritical water oxidation of organics is an improvement upon wet oxidation and represents a breakthrough in enhanced efficiency and reduction in capital investment. The major advantages of operating supercritically are:

- enhanced solubility of oxygen and air in water, which eliminates two-phase flow;
- rapid oxidation of organics, which approaches adiabatic conditions as well as high outlet temperatures with very short residence times;
- complete oxidation of organics, which eliminates the need for auxiliary off-gas processing;
- removal of inorganic constituents, which precipitate out of the reactor effluent at temperatures above 450^{o}C; and
- recovery of the heat of combustion in the form of supercritical water, which can be a source of high-temperature process heat or used to generate power in supercritical turbines.

These advantages arise primarily from the unusual properties exhibited by water under supercritical conditions.

The Properties of Supercritical Water

Above the critical temperature and pressure, the properties of water are quite different from that of the normal liquid or atmospheric steam. For example, organic substances are completely soluble (i.e., miscible in all proportions) in water under some supercritical conditions, while salts are almost insoluble under other supercritical conditions. These solubility characteristics are strongly dependent upon density.

A temperature-density diagram is shown in Fig. 1. The critical point (C.P.), which lies on the vapor-liquid saturation dome, occurs at 374^{o}C and 0.3 g/cm^{3}. The supercritical region lies above 374^{o}C and to the right of the 220 isobar. Near the critical point (e.g., between 300^{o}C to 450^{o}C and densities from 0.2 to 0.7 g/cm^{3}), the density varies very rapidly with relatively small changes in temperature at constant pressure.

Insight into the structure of the aqueous fluid in this region has been obtained from measurements of the static dielectric constant, which are also shown in Fig. 1 (2,3). The dielectric constants of some common solvents are given, for comparison, in Table 1.

The dielectric constant is a measure of the degree of molecular association. Normal liquid water has an ε of 80, largely as a result of strong hydrogen bonding. The dielectric constant of the saturated liquid decreases rapidly with increasing temperature, even though the density falls slowly.

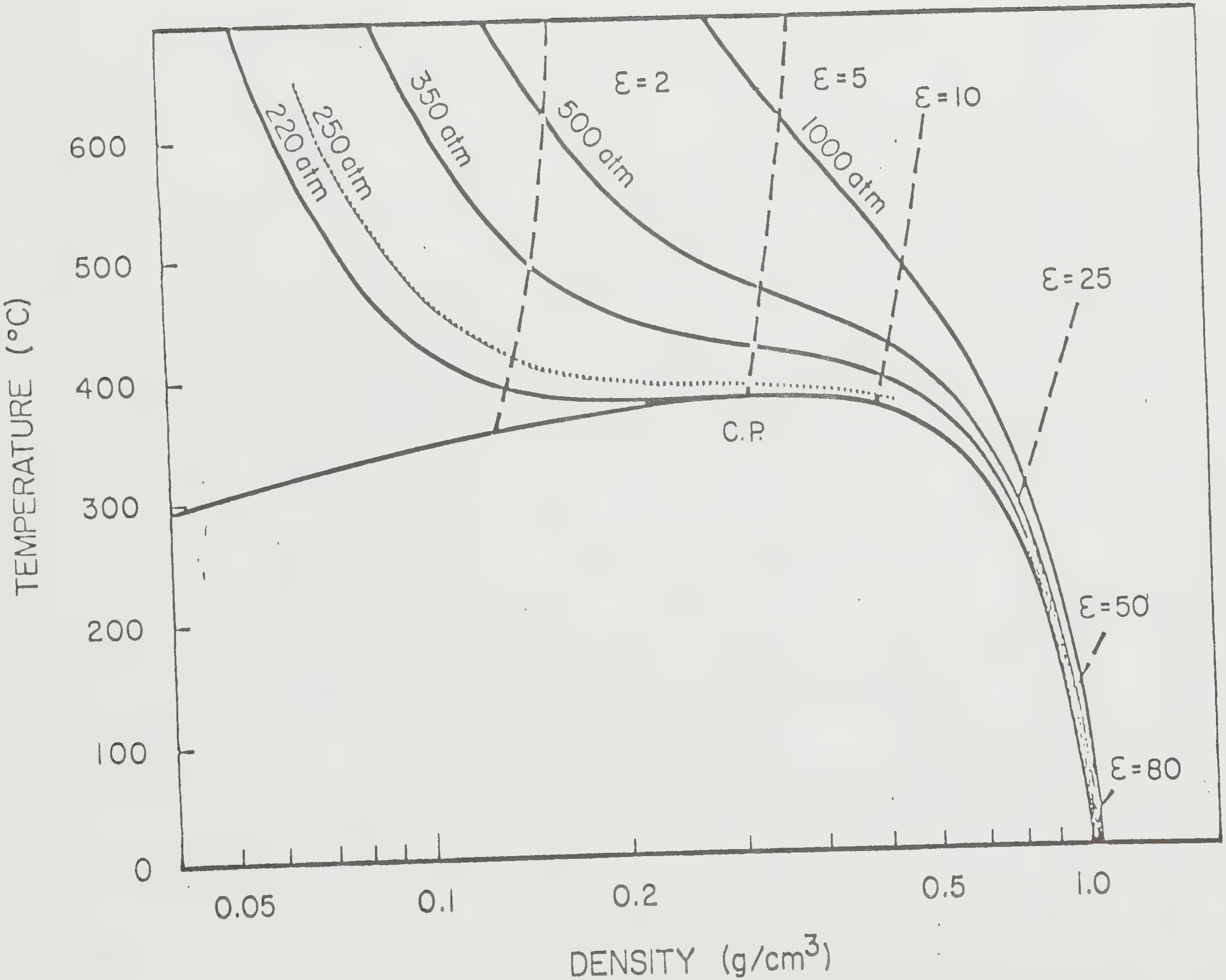


Figure 1

Temperature-density diagram for water with isobars (solid lines) and constant dielectric constant (dashed lines)

TABLE 1

DIELECTRIC CONSTANTS OF SOME COMMON SOLVENTS

Carbon Dioxide	1.60
n-Hexane	1.89
Benzene	2.28
Ethyl ether	4.34
Ethyl acetate	6.02
Benzyl alcohol	13.1
Ammonia	16.9
Isopropanol	18.3
Acetone	20.7
Ethanol	24.3
Methanol	32.6
Ethylene glycol	37.
Formic acid	58.

Since hydrogen bonding forces are strong only when molecules are in close proximity, small increases in density parallel relatively large decreases in short-range order resulting in a rapid decline in ε . At $130^{o}C$ ($\rho = 0.9$ g/cm^3), the dielectric constant is about 50, which is near that of formic acid; at $260^{o}C$ ($\rho = 0.8$ g/cm^3), the ε of 25 is similar to that of ethanol.

As density decreases further, the dielectric constant becomes less dependent upon temperature (i.e., the lines of constant ε in Fig. 1 become almost vertical). At the critical point, the dielectric constant is 5. Ramon spectra of HDO in this region indicate little, if any, residual hydrogen bonding (4). The major contribution to ε is now molecular association due to dipole-dipole interactions, which gradually decrease with increasing void volume.

Above $300^{o}C$, the temperature-density relationship becomes pressure-dependent (see Fig. 1). We shall follow the 250 atm isobar (which is a convenient pressure for supercritical operations). At $300^{o}C$, the ε of about 15 is similar to that of benzyl alcohol. Proceeding above $300^{o}C$ along the 250 isobar, we see ε dropping to 10 at $400^{o}C$, 5 at $420^{o}C$ and 2 at $490^{o}C$. Through the two hundred degree rise from 300 to $500^{o}C$, the dielectric constant varies from that of moderately polar to non-polar organic solvents.

While dielectric constant is not the sole determinant of solubility behavior, the solvent power of water for organics is consistent with the variation of ε, as described above. Benzene solubility in water is a good example (5,6). At $25^{o}C$, benzene is sparingly soluble in water (0.07 wt%). At $260^{o}C$, the solubility is about 7 to 8 wt% and fairly independent of pressure. At $287^{o}C$, the solubility is somewhat pressure dependent, with a maximum of 28 wt% at 200 to 250 atm. In this pressure range, the solubility rises to 35 wt% at $295^{o}C$; at $300^{o}C$, the critical point of the benzene-water mixture is surpassed. When the mixture becomes supercritical, by definition, there is only a single phase. Thus, the components are miscible in all proportions.

Other hydrocarbons exhibit similar solubility behavior. Aliphatic hydrocarbons are somewhat less soluble in water at comparable temperatures. Thus, higher temperatures are required to reach the same solubility as that of benzene. Binary mixtures of pentane-water and heptane-water become supercritical (and, therefore, completely miscible) at about $350^{o}C$ (5).

The locus of critical points of binary mixtures containing water have been reported for a variety of organic substances (e.g., ethane, ethylene, n-butane, 1,3,5 trimethylbenzene, naphthalene) and gases (nitrogen, carbon dioxide, ammonia, hydrogen, argon). Except for argon, all of the compounds studied to date are completely miscible with water above $374^{o}C$ at 250 atm. Argon is completely miscible above $390^{o}C$.

For densities less than 0.7 g/cm^3, the solubility of inorganic salts in water is as unusual as that of organics. At 250 atm, the solubilities of salts reach a maximum at 300 to $450^{o}C$. Beyond the maximum, the solubilities drop very rapidly with increasing temperature. For example, NaCl solubility is about 40 wt% at $300^{o}C$ and about 100 ppm at $450^{o}C$; $CaCl_2$ has a maximum solubility of 70 wt% at subcritical temperatures, which drops to 10 ppm at $500^{o}C$ (7). Given the fact that the dielectric constant of water is about 2 at $490^{o}C$ and 250 atm (see Fig. 1), it is not surprising that inorganics are practically insoluble.

Coincident with the loss of solvating power for inorganic salts, supercritical water also loses the ability to dissociate salts. For example, the dissociation constant of NaCl at 400-500°C and densities in the range of 0.35 is of the order of 10^{-4}. Thus, strong electrolytes become weak electrolytes in supercritical water.

The properties of water, as a function of temperature, are summarized in Fig. 2. We see that water goes through a complete reversal in solubility behavior toward organic and inorganic substances through the temperature range of 350-450°C. Below this range, the pattern is similar to normal liquid water: low organic and high inorganic solubility. Within the range, there is high solubility of both organic and inorganic substances. Above this range, inorganic salts are practically insoluble, and organic substances are completely miscible.

The Effect of Temperature on Destruction Efficiency

Over the past five years, we have conducted a number of studies of SCW oxidation using a bench scale unit, which has been described previously (8,9). We report here results of a study of the effect of temperature on destruction efficiency. The results, shown in Table 2 is a striking example, yet quite typical of other results we have obtained. The feed material for the tests of Table 2 were mixtures of 2,4-nitrotoluene in methylethyl ketone. All experiments were run with a residence time of 20 to 30 sec. Each column of Table 2 represents the average values of the two runs.

At the four temperatures of 404, 457, 513 and 574°C, the organic carbon destruction efficiencies were 92.5, 99.8, 99.93 and 99.998%, respectively. These results correspond to an increase in rate of over 3 orders in magnitude in the temperature range of 404 to 574°C. We have reason to believe that these results are limited not by reaction kinetics but by the rate of mixing of reactants. We have observed rates almost two orders of magnitude higher than the highest of Table 2 when operating with a new feed introduction device at 630°C (i.e., we have measured destruction efficiencies greater than 99.999% at residence times as low as 0.6 sec).

It is interesting to note the fate of organic nitrogen in the dinitrotoluene oxidation tests. At 574°C, the last column of Table 2, 94% of the nitrogen in the feed is recovered as N_2 and N_2O in the gaseous effluent and 6% is recovered as nitrate and nitrite ions in the liquid effluent. No NO, NO_2 or NH_3 was found in the gas phase nor was NH_3 found in the liquid phase.

In the other three columns of Table 2, the nitrogen material balance closure was poor because we did not analyze for N_2O in the gas phase and NH_3 in the liquid phase. In other experiments with dinitrotoluene, we found that ammonia and amines are formed at 400 to 500°C while N_2O is the major product at 500 to 550°C.

In no case have we found NO and NO_2 as products of oxidation of nitrogen compounds in SCW oxidation. At 600 to 650°C, we find N_2 and N_2O as the major products, even when the feed is primarily ammonia nitrogen. The N_2O component can be readily decomposed catalytically to N_2 and O_2 and, thus, SCW oxidation of nitrogen-containing organics is far less damaging to the environment than high temperature incineration.

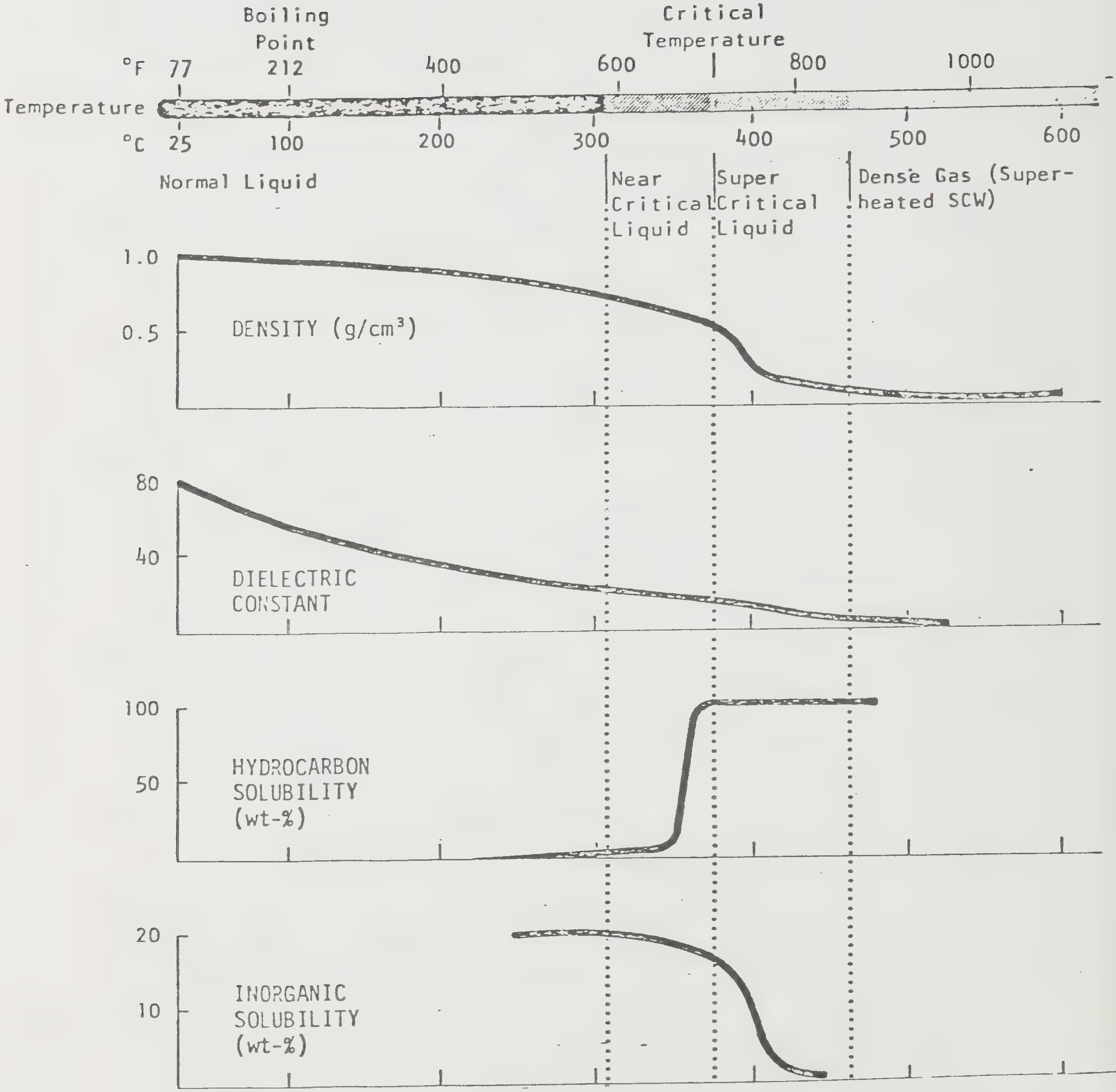


Figure 2

Properties of Water at 250 atm

Table 2

THE EFFECT OF TEMPERATURE ON DESTRUCTION EFFICIENCY; OXIDATION OF DINITROTOLUENE

Run No.	44/45B	42/43	39/40	69/70A
Feed Material	3% DNT/MEK	3% DNT/MEK	3% DNT/MEK	12% DNT/MEK
Temperature (^{o}C)	404	457	513	574
Carbon Analysis				
Organic Carbon In (ppm)	9,540	9,650	9,750	17,530
Organic Carbon Out (ppm)	712	15.7	6.9	0.4
Destruction Efficiency (%)	92.5	99.8	99.93	99.998
Total Carbon Recovered (%)	99.9	98.6	100.6	106.1
Nitrogen Analysis				
Organic Nitrogen In (ppm)	64	65	65	511
Nitrogen Out-Liquid (%)	58.7[a]	10.6[a]	2.2[a]	6.4[b]
Nitrogen Out-Gas (%)	NA	23.1[c]	23.1[c]	94.4
Total Nitrogen Recovered (%)	58.7	33.7	25.3	100.8
Gas Composition (mol %)				
O_2	16.96	11.88	15.04	15.08
CO_2	70.40	88.85	81.24	84.80
CH_4	0.10	0.06	0.18	ND
H_2	1.68	0.08	0.04	ND
CO	9.63	0.29	0.35	ND
N_2	0.10	0.06	0.06	0.41
N_2O	NA	NA	NA	0.57
NO	NA	NA	NA	ND
Liquid Products Containing Nitrogen (ppm)				
Dinitrobenzene	170.4	0.187	0.0066	<1 ppb
Dinitrophenol	6.1	0.002	0.0046	<1 ppb
Dinitrotoluene	60.5	0.535	0.0087	<1 ppb
Dinotrocresol	1.2	0.024	0.0018	<1 ppb

[a] Primarily organic nitrogen in liquid products
[b] Primarily nitrate and nitrite nitrogen
[c] Molecular nitrogen

The MODAR Process for Treatment of Aqueous Wastes

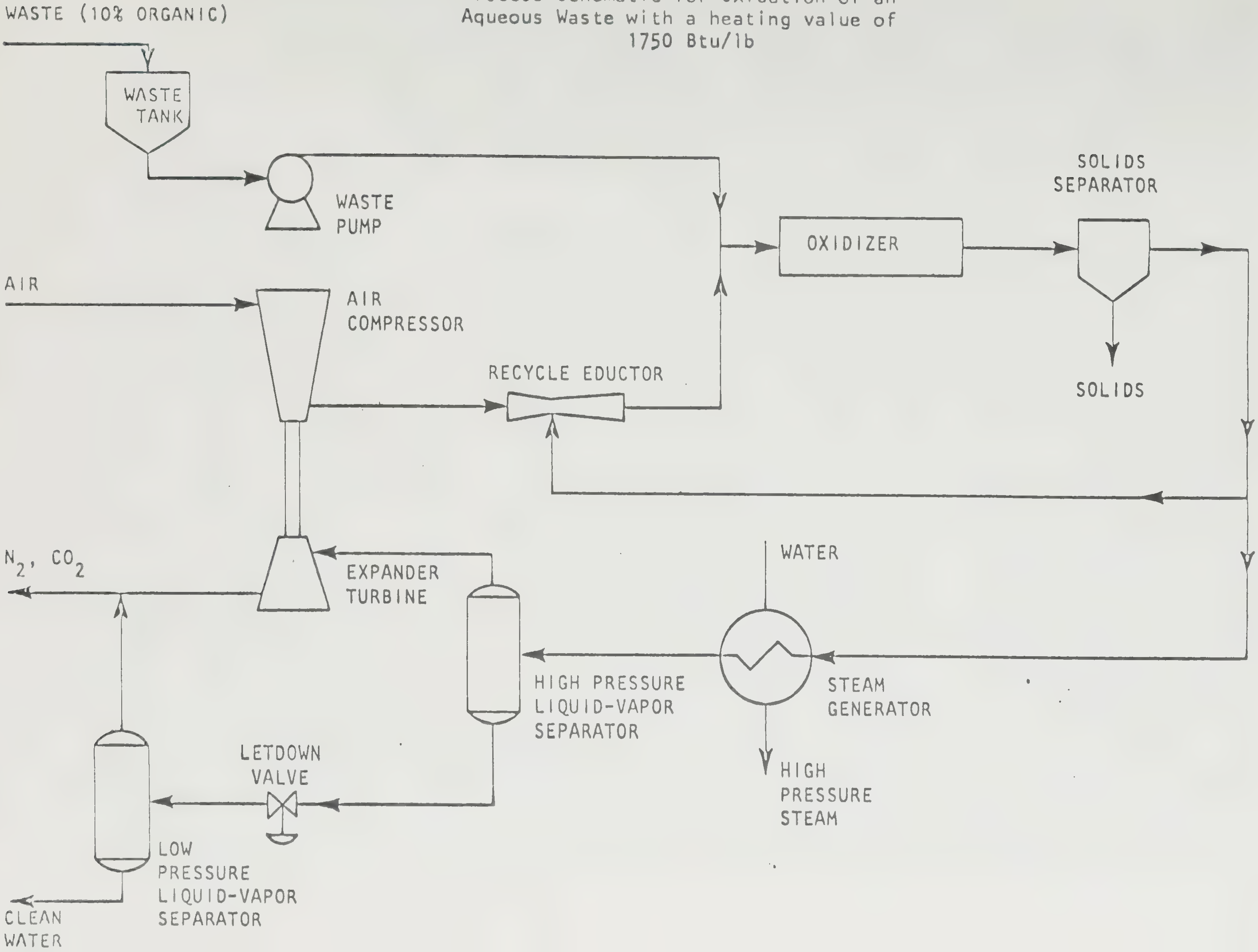
The MODAR process can be applied to wastes with a wide range of organic concentration. A schematic flowsheet for a MODAR process for treating an aqueous waste containing 10 wt% organic is given in Fig. 3. This process consists of the following steps:

1. The waste, as either an aqueous solution or a slurry, is pressurized and delivered to the oxidizer inlet. It is heated to supercritical conditions by direct mixing with recycled reactor effluent.
2. Oxygen is supplied in the form of compressed air, which is used as the motive fluid in an eductor to provide recycle of a portion of the reactor effluent. This inlet mixture is then a homogeneous phase of air, organics and supercritical water.
3. The organics are oxidized in a controlled but rapid reaction. The short residence times required allow adiabatic operation of the oxidizer. The heat released by combustion of readily oxidized components is sufficient to raise the fluid phase to temperatures at which all organics are oxidized rapidly.
4. The effluent from the oxidizer is fed to a cyclone. The solubility of inorganics is extremely low at the reactor effluent temperatures. Inorganic salts that are originally present in the feed or which form in the combustion reactions precipitate out of the fluid phase in the oxidizer and are separated here.
5. The fluid effluent of the solid separator is a mixture of H_2O, N_2, and CO_2. A portion of this is recycled through the eductor to provide supercritical conditions at the oxidizer inlet.
6. The remainder of the effluent is available as a high temperature, high pressure fluid for energy recovery. This stream is cooled to a subcritical temperature in a heat exchanger which serves to generate low pressure or high pressure steam.
7. Now at a subcritical temperature, the mixture has formed two phases and enters a high pressure liquid-vapor separator. Practically all of the N_2 and most of the CO_2 leaves with the gas stream. The liquid consists of water with an appreciable amount of dissolved CO_2.
8. The gas stream can then be expanded through a turbine to extract the available energy as power. A portion of the power is used for compression of the inlet air.
9. The liquid from the high pressure separator is depressurized and fed to a low pressure separator. The vapor stream is primarily CO_2 which is vented with the gas turbine effluent. The liquid stream is clean water.

The destruction efficiency (defined herein as the conversion of organic materials in the feed to final oxidation products of CO_2, H_2O and acids or oxyacids of heteroatoms and metals) is a function of reactor temperature and residence time. We have found that a reactor effluent temperature in the range of 600 to 650°C and residence time of 5 sec are sufficient for a destruction efficiency of more than 99.999%. Higher temperatures could be used to reduce the residence time. However, at 5 sec residence time, the reactor cost is a small fraction of total capital cost and, therefore, there is not much incentive to try to reduce reactor volume by operating above 650°C.

Figure 3

Process Schematic for Oxidation of an Aqueous Waste with a heating value of 1750 Btu/lb



Increasing either temperature or residence time will result in increased destruction efficiency. The oxidation kinetics appear to be approximately first order in organic concentration. Thus, in theory, doubling the reactor length and, thereby, doubling the residence time from 5 to 10 sec should result in doubling the logarithm of destruction efficiency; in other words, 99.999% should become 99.9999999999%! [Of course, the analytical techniques required to document such high destruction efficiencies are not available.]

As expected, we do not form NO or NO_2 during oxidation of organic nitrogen or ammonia below 650°C. The primary products of oxidation of these compounds are N_2 and N_2O (nitrous oxide); the latter can be readily decomposed to N_2 and O_2. Heteroatoms such as chlorine, sulfur and phosphorus are oxidized to HCl, H_2SO_4 and H_3PO_4, respectively, or form the corresponding salts if cations in sufficient concentration are present.

For the process configuration illustrated in Fig. 3, the reactor exit temperature is a direct function of the heating value of the feed. To attain a temperature of 600 to 650°C, the waste should contain about 1,750 Btu/lb or 4,050 J/g, which is the heating value of an aqueous solution of about 10 wt% benzene (heat of combustion of 17,500 Btu/lb or 40.5 kJ/g) or 14 wt% ethanol (12,800 Btu/lb or 29.7 kJ/g). If the waste is more concentrated or otherwise has a higher heating value, it could be blended with more dilute waste or, if unavailable, with water. In the latter case, the added water would be recovered from the process effluent in a form which is pure enough to be used as process water in most applications.

The energy released by combustion is contained within the reactor effluent as thermal energy. As shown in Fig. 3, it could be recovered as heat in the steam generator and/or power from the expansion turbine. The energetics of the SCW oxidation process are such that the amount of power available for recovery is substantially more than that required to compress the air and waste. The overall process is somewhat analogous to a gas turbine power cycle. However, many applications require systems which are small (by chemical process industry standards) and capital-intensive. In those cases, power recovery cannot be justified on economics and, thus, the heat of combustion and the energy input for air compression are simply recovered as steam.

Disposal Costs as a Function of Waste Throughput and Organic Content

The major component of the capital cost of an SCW oxidation system is the cost of the air compressor. To a first approximation, systems can be sized and costed on the basis of oxygen throughput. Thus, the chemical oxygen demand (COD), heating value and flow rate of waste are the only parameters required to develop a preliminary estimate of the cost of waste treatment. For most organic wastes, the ratio of heating value to oxygen demand is about 5,000 to 6,000 Btu/lb O_2 (12 to 14 kJ/g). Hence, oxygen demand can be approximated from heating value and, therefore, heating value and throughput alone can be used to develop a preliminary estimate when COD is not available.

Disposal costs for SCW oxidation of aqueous wastes are given as a function of throughput in Table 3. These costs are projected costs to a waste generator, based on the following assumptions:

Table 3

DISPOSAL COSTS FOR DILUTE AQUEOUS WASTES

Waste Capacity		Heat Release Rate		Processing Cost**	
gal/day*	ton/day*	Btu/hr	J/S	$/gal*	$/ton
10	0.04	6,000	2,000	(Bench Scale)	---
500	2	300,000	90,000	(Demo Scale)	500
2,500	10	1,500,000	400,000	0.80	200
5,000	20	3,000,000	900,000	0.50	120
12,500	50	7,300,000	2,200,000	0.25	60
25,000	100	14,600,000	4,300,000	0.15	40

---

* based on an aqueous waste with 1,750 Btu/lb or 4.1 kJ/g heating value, which is approximately 10 wt% of benzene-equivalent

** tolling cost to waste generator (see text)

- an SCW system is installed at the site of waste generation
- the waste disposer owns and operates the unit for the waste generator
- the unit is not equipped with a power recovery turbine.

Table 3 is directly applicable to a waste containing 10 wt% benzene-equivalent. When a variety of waste streams are candidates for disposal, it is usually desirable to blend to the 10 wt% range. If the aggregate waste mixture is more concentrated than that, water can be added to make 10 wt%, but then the cost per unit of waste is proportionately higher than that shown in Table 3. For example, assume that we have an application involving 30 ton/day of a waste with a heating value of 2,600 Btu/lb (6 kJ/g), which is about 15 wt% benzene-equivalent. The heat release rate would be 2,600*2,000*30/24 or 6,500,000 Btu/hr. From Table 3, the processing cost would be somewhat higher than that of the 7,300,000 Btu/hr system; assume it is $70/ton, based on 10 wt% benzene. To extrapolate to a concentration of 15 wt%, we must multiply by 15/10. Thus, the projected cost would be about $100/ton of waste.

For wastes with heating values below 1,750 Btu/lb, auxiliary fuel could be added to make up the required heating value. In such cases, the auxiliary fuel cost must be added to the estimate obtained from Table 3. For example, if we had 20 ton/day of a waste containing 5 wt% benzene equivalent, then we would have to add 1 ton/day fuel to reach the 10 wt% level. The heat release rate would be about 3,000,000 Btu/hr and the disposal cost would be about $130/ton of waste ($120/ton from Table 3 plus $10/ton for the added fuel).

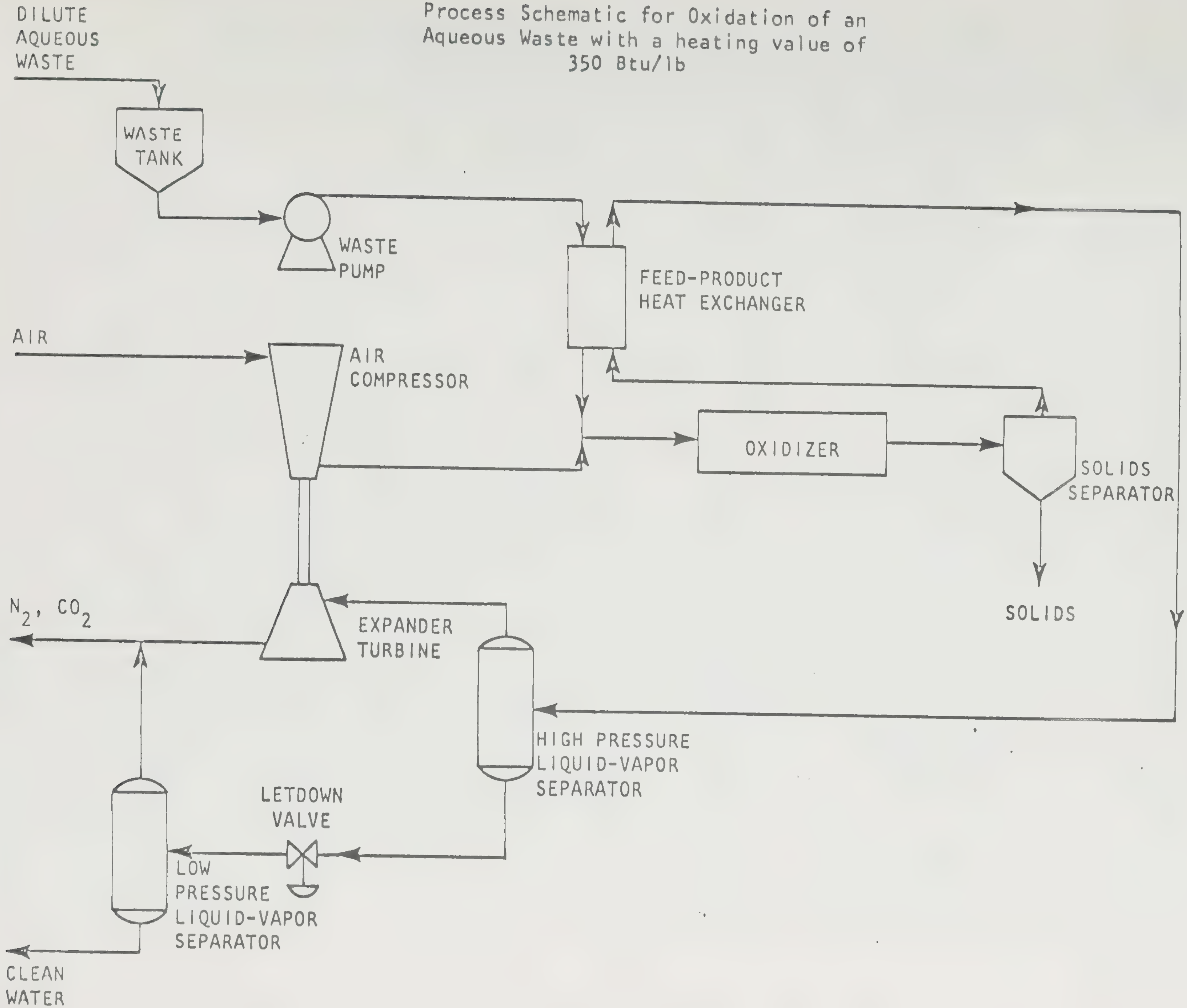
In this last example, the cost of auxiliary fuel was not a significant fraction of the overall cost. However, when the waste throughput is larger and the unit cost is smaller, fuel cost can be appreciable when treating a very dilute waste. In such cases, it is more economical to use a regenerative heat exchanger rather than a steam generator, as shown in Fig. 4. This process configuration differs from that of Fig. 3 by addition of a feed-effluent heat exchanger and deletion of steam generator and eductor. In this manner, the minimum heating value of the feed for autogenic operation is 350 Btu/lb (800 J/g), which is a concentration of 2 wt% benzene-equivalent. For the same heat release rate, the process of Fig. 4 can treat five times as much waste (at 2 wt%) as that of the process of Fig. 3 (at 10 wt%). This increased waste volume more than compensates for the higher capital cost due to the regenerative heat exchanger. The net result is that very dilute waste can be processed at a cost per ton which is somewhat less than that shown in Table 3.

Advantages of the MODAR Process

As a waste destruction process, the MODAR concept has several advantages over conventional processes. The chemical reactions that occur are carried out in a closed system, making it possible to maintain total physical control of waste materials from storage, through the oxidation process, to the eventual discharge of the products of combustion. This feature provides positive assurance of environmental protection. In addition, bench-scale results have demonstrated essentially complete combustion of chemically stable hazardous and toxic materials. The process can be adapted to a wide range of feed mixtures and scales of operation. Systems can be designed as skid-mounted,

Figure 4

Process Schematic for Oxidation of an Aqueous Waste with a heating value of 350 Btu/lb



transportable units and as larger scale stationary units. The process is capable of generating all the power required for air compression and feed pumping and, thus, can have no net energy requirement for system operation.

Conclusions

Dilute aqueous wastes (1-20 wt% organic) can be destroyed by supercritical water oxidation at projected costs significantly below those of incineration or carbon adsorption. At the larger end of the scale of operation, SCW oxidation costs can be competitive with land-based disposal methods (e.g., deep-well injection) especially if such alternatives require waste transportation over sizable distances.

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MOBILE TECHNOLOGY SYSTEMS

By

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The application of mobile technology to site cleanups, emergency response and industrial cleaning is emerging as an alternative to conventional methods. "Conventional methods" is a broad term which describes the pump-it-out, dig-it-up, haul-it-away and dump-it scenarios which have long been the method of economic choice for hazardous waste management. Rising costs of land disposal are a powerful motive for the development and application of other methods, as is the general perception that, ultimately, the landfilling of hazardous wastes will be discontinued.

Several mobile technologies, from the most rudimentary volume reduction techniques to multi-step treatment processes, have recently been applied. These applications are reviewed in detail, with emphasis on comparative costs to other alternatives.

Mobile technology is the use of chemical engineering know-how. Equipment capable of performing one or more unit operations is assembled for a particular processing need, operated and then disassembled. At IT Corporation we began calling it "MOTECH" for convenience, and the name seems to have stuck. The usefulness of the term is that it denotes no particular piece of equipment. MOTECH is an ad hoc assemblage of process equipment, put in place for a period of about a month. At the end of the job, the capital assets are retained for use on the next job. This distinguishes MOTECH economically from plant construction, followed by salvage. The equipment cost for a MOTECH job is about 6% of new equipment cost. When used equipment is assumed in the cost analysis along with a generous allowance for salvage value, equipment cost for processing is still 2-3 times more than the MOTECH concept.

The simplest processes are solid/liquid separation processes for volume reduction. The use of belt filter presses is widespread in the United States for mobile solid/liquid separation. Processing rates are medium to high, compared to other devices, and the high pressure press effect assists in producing stable materials for placement in containment cells. A major manufacturer of herbicides in the south used a MOTECH belt press for removing sludge from a holding pond. The sludge generated by the plant's wastewater treating system was dredged, dewatered on a belt press, and then landfilled on site. The job was completed for about the cost of conventional (nonhazardous) excavation and disposal ($15-$20 per yard). This work represents the simplest level of MOTECH; the only specification is to reduce volume. In this case, the dewatered material was nonhazardous and off-site disposal was not required.

In November 1984, a major Class I disposal site in the Los Angeles area was closed. Generators in the Los Angeles basin faced a 3-4 fold increase in transportation and disposal costs.

In September, routine cleaning of the wastewater treatment plant for a major Southern California refinery was accomplished using new mobile centrifuge technology. Main API separators and forebay were cleaned with IT Corporation services crews. Approximately 65,000 bbls of sludge and water generated by conventional industrial cleaning operations were reduced in volume by over 60%. The refinery reported a 4:1 reduction in disposal volume from previous conventional methods used for cleaning the separator. Total cost, including industrial cleaning, was less than $600,000. This is about 2/3 of the cost of conventional <u>transportation</u> and <u>disposal</u> at a Class I disposal site.

This job represents the second level of MOTECH in that several specifications were met by adapting solid/liquid separation technology to the situation, i.e., volume reduction was the objective, but there was some complexity associated with meeting environmental standards. Previous conventional cleaning operations had resulted in upsets to the refinery wastewater treatment plant. Pretesting of the centrifuge process was conducted at IT Corporation's Vine Hill, California, treatment facility to establish production rates, effluent quality and chemical requirements. Chemical treatment was used to enhance oil recovery from the centrifuge. Processing resulted in 930 tons of cake produced, and 800 bbls oil recovered.

Operations were conducted under an experimental permit by the South Coast Air Quality Management District. During all periods of centrifuge operation the system was maintained under negative pressure by a carbon adsorption system. The effluent air discharge was monitored frequently. No hydrocarbon emissions were detected. H_2S was detected on the final day of operation, which resulted in modifications to the equipment to improve its absorptive capacity.

The process was repeated in a second Los Angeles area refinery a month and a half later. Improved air pollution control equipment resulted in virtually no emissions. The job differed slightly in that an open surge basin in the refinery was cleaned using a dredging system. The results were that 750 tons of solid cake were removed from the basin, in a week, at half the cost per ton of doing the job with an industrial cleaning crew.

The full capability of MOTECH was used on two jobs in 1984-85. Contaminated soil at a major chemical plant in the south was washed and neutralized using a seven-step Mobile Technology process. The soil was screened and washed to remove sea shells which would interfere with the neutralization process which followed. After neutralization, soil was dewatered with a mobile centrifuge and clarified water was discharged to the plant wastewater system. Solids, which consisted of washed shells and decontaminated soils, met State requirements for placement in an on-site landfill, which eliminated all off-site disposal. Three million pounds of soil were processed for a cost of about $250,000.

A MOTECH job, in mobilization at the time of this writing, requires a mobile acid neutralization plant near Richmond, California. The job is to treat zinc stripping waste. The process plant includes pH neutralization, clarification, metal hydroxide precipitation, sludge dewatering and filtration. The plant discharge is well within POTW pretreatment standards. Dewatered metal hydroxide sludges meet free liquid requirements for landfill. The capacity of the plant, 200 gpm, is large enough to treat five million gallons in less than a month. The cost is 1/3 the cost of conventional treatment and disposal ($600,000-$700,000 vs $1.8-$2.5 million).

In summary, the costs of land disposal are growing at an alarming rate. Innovative applications of processing technology are clearly called for to reduce the costs of hazardous waste management. Properly designed mobile systems can be adapted to needs ranging from simple volume reduction to process solutions which meet rigorous environmental specifications. Current economics favor such solutions.

INCINERATION: THE PERMANENT SOLUTION

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To insure that landfill disposal posed no threat to human health or the environment, the 1976 Resource Conservation and Recovery Act (RCRA) legislation established guidelines for the proper management of hazardous waste landfill sites. As an incentive for proper management, this legislation included the concept of "cradle to grave" generator liability. Under this concept, a generator's liability does not end when his waste is disposed of in a landfill. The generator's liability for his hazardous waste continues as long as his waste is in the landfill. Even with the guidelines and incentives of the RCRA legislation, the environmental and human health problems associated with landfill disposal have persisted. Recognizing that landfills are at best a temporary solution for hazardous waste disposal, current State and Federal legislation has been enacted which gradually phases out landfill disposal. To eliminate the persistent problems of long term liability and to comply with current legislation, incineration is now the permanent disposal solution for hazardous waste generators.

The problem with long term liability is that landfills continue to leak. Stringfellow Acid Pits in Southern California made the Environmental Protection Agency's (EPA) cleanup priority list because it has severely contaminated the drinking supply of thousands of people. BKK landfill in Southern California was closed last fall to hazardous wastes because of gas leaks and groundwater contamination. New studies have shown one of the only operating hazardous waste landfills in California-Chemical Waste Management in Kettleman Hills-may also be contaminating groundwater. Cleanup of sites like these costs millions of dollars per site. Generators whose wastes are in these landfills are liab le for the cleanup costs of these sites. Generators

must realize the only way to completely eliminate future liability is to permanently dispose of hazardous waste through incineration.

Because of these problems associated with landfill disposal, the State of California established regulations banning land disposal of hazardous wastes. A specific timetable for the gradual phaseout of landfill disposal was established. California has already banned cyanides, heavy metals (mercury, lead, chromium, etc.), strong acids, polychlorinated biphenyls (PCB's), pesticides and flammable liquids from landfills. Liquid halogenated material (containing chlorine, fluorine) were banned this past January 1,1985. Halogenated sludges and solids will also be banned beginning July 1, 1985.

The Federal government has followed California's lead in the phaseout of landfill disposal by reauthorizing RCRA last fall. The new RCRA establishes stringent requirements for disposal of hazardous waste on land and encourages generators to use all possible alternatives to land disposal of wastes. A schedule has been established for the EPA to review certain hazardous wastes including the already banned "California wastes" as well as others like dioxins, chlorinated aromatics and refining wastes. According to a specific timetable, the EPA must then determine whether or not they can be disposed of on land.

From this, it is clear that incineration is the only permanent solution to landfill disposal. However, at present California generators have only three incineration facilities available to them within 2000 miles. Although there are 17 companies operating hazardous waste facilities in California, only one of these accepts wastes from off-site generators. The other 16 operate on-site facilities, incinerating only material thev themselves generate on-site.

The onlv off-site facility is the General Portland Cement kiln in Lebec, CA, operated by Systech Corp. At this facility, cement is produced from limestone by roasting slurry in a large rotary kiln incinerator.

In 1982, General Portland Cement was issued a temporary permit on an experimental basis to burn chemical wastes as supplemental fuel for their kiln. The cement kiln is allowed to supplement up 25% of its heating value requirement with high heating value waste. Only high heating value wastes such as lacquer thinners and alcohols are accepted. This insures that when all the wastes are blended, a heating value of greater than 10,000 BTU/pound

will be maintained. Specific waste restrictions are set for the content of halogens, sulfur, nitrogen, metals, benzene, PCB's, and ash in the waste. Only bulk loads of prequalified wastes are accepted.

Outside of California, the closest hazardous waste incinerator is operated by Rollins Environmental Services in Deerpark, Texas. The incinerator consists of a rotary kiln and liquid injection incinerator, both feeding a common secondary chamber.

A typical rotary kiln incinerator, such as Rollins', consists of a cylindrical chamber positioned at a slight incline to the horizontal. Wastes are injected into the higher end of the chamber and pass through the combustion zone while the chamber rotates. The rotation exposes the waste in the chamber to heat and oxygen required to destroy the waste. Ash is removed from the lower end of the kiln. Retention times vary according to the type of waste, from seconds for gases to hours for some bulk solids. Kiln temperatures typically range from 1600-3000 degrees Fahrenheit.

The liquid injection portion of Rollins' facility is the most widely used incinerator design in the United States today. A typical liquid injection incinerator consists of a combustion chamber and atomizing nozzles. pumpable waste is atomized into fine droplets and is mixed with air. The waste is then burned in suspension. The liquid injection incinerator can be positioned either vertically or horizontally. Operating temperatures range from 1800-3000 degrees Fahrenheit. Retention times range from 0.5 seconds to two seconds depending on the characteristics of the waste.

Incorporating these types of incinerator designs, Rollins is able to burn a diversity of wastes including halogenated solvents, petroleum refinery waste, plastics and other organics. This facility is one of the few commercial facilities approved to incinerate liquid and solid PCB waste. Solid and semi-solid wastes must be packed in fiber drums either by Rollins or the generator. Liquids are analyzed and blended according to their burn and scrubbing characteristics.

The only other incinerator within 2000 miles which accepts off-site waste is operated by Chemical Waste Management (formerly by SCA Services) in Chicago, Illinois. This facility utilizes a rotary kiln which operates at 1600-1800 degrees Fahrenheit. The combustion gases from

the kiln pass through a secondary combustion chamber where they are further burned at higher temperatures to insure complete combustion.

The incinerator accommodates many types of combustible liquid, solid and semi-solid waste including solvents, halogenated hydrocarbons, pesticides and other organics. Most of the waste they are currently burning is PCB contaminated waste. Fluorinated material such as "Freon" residues will not be accepted because fluorine reacts to form hydrofluoric acid which corrodes their fiberglass gas scrubbers. All wastes must be packed in fiber drums prior to incineration.

These are currently the closest incineration facilities available to California waste generators for permanent disposal of waste. Because of this limited accessibility to disposal alternatives, and of the regulations banning land disposal of hazardous waste, Omega Chemical Corporation is building an incineration facility to serve the generators of California.

The site chosen for the new facility is located in an industrial area of Irwindale (northeast L.A. basin). Omega is working with the California Energy Commission, EPA, South Coast Air Quality Management District, Department of Health Services and the City of Irwindale to prepare all required applications and tests to obtain approval to construct and operate in Irwindale.

Omega's incinerator will be a circulating fluidized bed. The system will be designed and manufactured by G.A. Technologies of San Diego. Circulating bed combustion has been used since the mid-1970's to burn fossil fuels for heat recovery. Recently, because of its unique design characteristics, it is considered one of the best technologies available for the incineration of hazardous waste.

A circulating fluidized bed incinerator consists of a vertical chamber containing limestone. Air is forced up through the bed at high velocity which causes the bed to act like a boiling liquid. The bed is brought to temperature by the combustion of auxiliary fuel. Waste material is injected into the bed and combustion occurs in the turbulent bed within two seconds. The turbulence causes rapid and uniform mixing which allows for the combustion temperatures of 1400-1600 degrees Fahrenheit. Unreacted liquid waste and large particulate matter is recirculated through a hot cyclone back to the feed section until combustion is complete. Noncombustible material is

removed as ash from the unit. A baghouse is utilized to remove particulate matter from the combustion gases. Heat generated from the combustion of waste will be used to generate high pressure superheated steam. The steam will pass through a turbine to generate electricity.

The circulating fluidized bed design has several advantages. The limestone bed reacts with and neutralizes most of the hydochloric acid and sulfur dioxide produced during combustion. This eliminates the need for complex gas scrubbing devices. This neutralization also reduces corrosion within the chamber. The homogeneous bed of heated particles allows wastes to be combusted quickly at low temperatures. Low temperatures help eliminate additional NO_x formation during the combustion process.

The diversity of this unit will allow the incineration of solids, sludges, slurries, and liquids. A variety of wastes will be accepted including still bottoms from solvent reclamation, chlorinated solvents, thinners, paints, oil waste and other organics. Carcinogens (such as PCB's and dioxins), radioactive and infectious wastes will not be accepted.

All waste incinerated must meet the EPA requirements of 99.99% destruction of the waste. After a generator's waste is destroyed, the generator will be sent a "Certificate of Destruction" stating his wastes were completely and permanently destroyed. Therefore, by incinerating hazardous wastes, any future liability of waste disposal is completely eliminated forever.

To eliminate long term liability and to comply with current legislation, land disposal is no longer a viable disposal alternative. Landfills continue to leak and the generator's liability continues to grow. State and Federal legislation has addressed these landfill problems by banning land disposal of hazardous waste. Thus, for generators of hazardous waste incineration is the permanent solution.

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THE TRANSFER STATION -- A PARTIAL ANSWER TO THE SMALL GENERATOR

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The Resource Conservation and Recovery Act (RCRA) was reauthorized by the Congress in October 8, 1984, and was signed into law on November 8, 1984. Among the many changes to RCRA is the reduction of the exemption level for hazardous waste generators from 1,000 kilograms (kg) per calendar month (about 2,000 pounds) to 100 kilograms (kg) per calendar month (about 220 pounds). Under the changes, EPA is required to issue new regulations for hazardous waste generators who generate between 100 kg/month and 1,000 kg/month. This is the first attempt by the federal government to regulate hazardous waste generated by small business and industry.

Industries that generate less than 1,000 kg/month of hazardous waste are considered as small quantity generators (SQG's). In many states SQG's are exempted from some of the regulatory requirements, specifically storage, manifesting, and recordkeeping. However, hazardous wastes generated by SQG's have the same potential for creating environmental contamination problems if mismanaged as do the regulated hazardous wastes.

Although California has addressed the small quantity generator issue, for all practical purposes, it does not recognize the SQG's any differently than larger generators. However, many other states by adoption of the federal program have not had to address this issue. As you know, State implementation of the hazardous waste program must be

consistent with the federal program before full/final authorization can be granted by the U.S. EPA.

Many of the owners and operators of municipal solid waste management systems that we have contacted are very concerned with these new legislative requirements.

Many SQG's discharge all of their wastes in municipal solid waste management systems; therefore municipal solid waste management systems will be faced with the problems of receiving hazardous waste manifests on August 5, 1985.

Municipal solid waste systems that collect wastes from SQG's will be faced with paperwork requirements attendant with being a hazardous waste transporter provided the SQG's continue to discharge their hazardous waste into a municipal solid waste management system.

Municipal solid waste storage, transfer, treatment, recovery and disposal facilities will begin to receive the manifest and while the legislation is not clear relative to the responsibilities of municipal solid waste management facility owners regarding the handling of the manifest, it seems prudent for owners/operators to follow the requirements which now exist for owners/operators of hazardous waste management facilities. Many owners/operators we have contacted plan to discontinue services to SQG's.

It may be assumed that many SQG's are not aware of the legislative changes of RCRA; that they now generate hazardous waste; or that they may have been in violation of the law before it was amended; certainly it is essential that they now understand their responsibilities.

Should SQG's take other actions to remove their hazardous waste from municipal solid waste management systems, the destiny of those wastes is important to local government if public health and environmental quality is to be protected.

In response to these concerns and in response to the expanding hazardous waste markets, AEMC has developed a program to provide the needed services to the SQG's. The key to this service is the hazardous waste transfer station.

The hazardous waste transfer station provides an efficient and cost-effective waste management system and service to the SQG's. The transfer station, if properly operated, provides the SQG's with safe, reliable, economic storage and transfer services for their waste streams. This service includes expert

packaging, labeling, and handling in accordance with the D.O.T. and a location where wastes can be analyzed to identify waste type, hazard class, and compatibility prior to transporting to and from the transfer/storage facility. When maximum transportation volumes are obtained for each compatible waste stored at the facility, the wastes are then transported to an approved disposal facility.

More specifically, the benefits of the transfer station are:

. Reduces generator accumulation period.
. Reduces size of generator storage accumulation areas.
. Provides an economical alternative to direct disposal.
. Reduces generator storage risks.
. Provides generators with safe, reliable storage of most wastes.
. Offers long-haul transporters overnight storage.
. More economical for small generators to store than to transport direct to disposal site due to premium prices paid for 1-2 drum pickup.
. Immediate storage in emergency situations.

Other benefits that should be available are:

. Highly trained professionals with broad a range of experience and knowledge related to hazardous materials.
. 24-hour emergency response capability.
. Command post responsibility.
. Mobile laboratory to identify materials and to perform hazardous caterization (Haz-Cat).
. Licensed, registered, transportation--vacuum trucks, drum transporting vewhicles, bin trucks, dump trucks, etc.

Cities in an effort to develop effective solutions to hazardous waste mismanagement problems have found that a better understanding of the current hazardous waste situation was needed. Many cities have conducted new or revised industrial waste surveys. The surveys identify the amount, type, and source of hazardous and nonhazardous industrial wastes generated in their area. An assessment was also made to determine the need for local hazardous waste management facilities.

The survey questionnaires are usually divided into three sections to provide the information needed to meet the objectives of this study. The objectives are:

1. To determine the type and quantity of hazardous waste generated in the area.

2. To identify current waste disposal practices, and

3. To determine the need for local hazardous waste management facilities.

The studies also assessed the current level of understanding among the small unregulated industries. The study approach is to survey all businesses within SIC specific categories as shown here:

COMMON INDUSTRIAL PROCESSES GENERATING HAZARDOUS WASTES BY SIC INDUSTRIES

SIC Code	Type of Industry	Common Industrial Processes
1700	Special Trade Contractors	Paint stripping and sandblasting
2400	Lumber and Wood Products	Laminating, sanding, planing and fabricated millwork
2700	Printing, Publishing and Allied Products	Letterpress, lithography, gravure and screen printing, bookbinding, typesetting, engraving, etching, photoprocessing and photocopying
2800	Chemicals and Allied Products	Mixing, grinding, tinting and thinning, fermentation, purification, extraction and crstallization
2900	Petroleum Refining and Related Industries	Bulk storage and transfer
3000	Rubber and Misc. Products	Etching, molding and carving
3400	Fabricated Metal Products	Electroplating, anodizing, etching, machining, grinding, polishing, painting, impact and pressure deformation, shearing, welding, soldering, brazing, heat treating, sandblasting, solvent degreasing, vapor degreasing, acid and alkaline rinsing and cleaning, assembly, calibration and testing

3500	Machinery Except Electrical	All listed in 3400 except electroplating and anodizing
3600	Electrical Machinery Equipment and Supplies	Electroplating, electroless plating, etching, acid and alkaline rinsing, soldering, solvent degreasing, lithography, assembly, calibration and testing
3700	Transportation Equipment	All listed in 3400
3800	Professional and Scientific Instruments	Soldering, solvent degreasing, assembly, calibration and testing
3900	Miscellaneous Manufacturing Industries	Electroplating, etching, acid and alkaline rinsing, sandblasting, polishing, grinding, soldering, burnishing and painting
5080	Drum Reconditioning	Acid and alkaline rinsing, solvent degreasing, sandblasting and painting
7261	Funeral Services	Embalming and cremation
7395	Photofinishing Laboratories	Photoprocessing
7397	Commercial Testing Laboratories	Analytical chemistry
7500	Automotive Repair Services and Garages	Acid and alkaline rinsing, solvent degreasing, welding, machining, sanding, grinding and painting
7535	Paint and Body Shops	Sanding, grinding, welding, soldering, brazing, solvent degreasing and painting
7539	Radiator Repair Shops	Acid and alkaline rinsing, solvent degreasing, soldering, brazing, and painting
8000	Medical and Health Services	Laboratory analysis and photoprocessing

9100	Federal Government	All items listed in 3400, 3600, and 3800

The general concensus from these surveys is that the SQG's would use a hazardous waste transfer station if available.

Another area for which transfer stations can provide services is in supporting household quantity hazardous waste collection programs.

The problems of hazardous waste disposal from households are well recognized by most cities and regional solid waste programs. Even though individual households dispose of relatively small amounts of hazardous materials, these materials have a cumulative effect. Most of the materials end up at one of three places: 1) landfills, 2) the sewer system, or 3) illegal dump sites throughout the cities and surrounding areas.

The U.S. EPA estimated in early 1980 that up to ninety thousand (90,000) land-disposal sites, i.e. nonhazardous waste sites were contaminating surface and groundwaters.

Refuse workers have been injured--sometimes seriously--while unknowlingly picking up trash containing toxic chemicals. Such incidents involve being overcome by toxic fumes created through the mixing of incompatible chemicals to being splashed by acids. Fires have started in "dump trucks" causing serious damage to the equipment.

Some authorities believe that disposal of toxics via landfills and septic systems pose a threat to groundwater and drinking water. Septic and sewer systems are not designed to handle hazardous wastes and large amounts can cause the system to malfunction sending both toxic and conventional wastes directly into connecting waterways.

Some people are aware of the dangers associated with unsafe disposal of household toxics and have chosen to store such products in their garage over the years. Storing excessive amounts of hazardous chemicals in and around the home put firemen at increased risks when responding to residential fires. It also increases the chance for a poisoning to occur--especially if small children are present in the home.

Hazardous waste transfer stations have the opportunity to provide a service to household quantity generators to collect their waste streams.

Numerous communities throughout the country have held successful hazardous/toxic waste collection programs. These programs have provided an alternative to improper disposal of hazardous waste and have aided in protection of the environment, particularly the groundwater. Perhaps more importantly, they have provided a vehicle to educate the public on the hazardous waste disposal problem.

BIOHAZARDOUS (INFECTIOUS) WASTE MANAGEMENT

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Hospitals and health care oriented facilities produce large amounts of infectious waste material which must be properly managed to avoid contamination and infection of human and animal receptors. Although most health care facilities have traditionally taken steps to control and prevent infection due to such waste materials, the California Legislature has recently tightened requirements for infectious waste management by declaring that infectious waste is to be managed as a hazardous waste pursuant to regulations administered by the Toxic Substances Control Division of the State Department of Health Services. Thus, the term "biohazardous" has become more appropriate than the term "infectious" in describing the waste material and the approach taken in the new regulatory effort. Generators, transporters and disposers of biohazardous waste are having to change the way they operate to come into compliance with these new rules.

Biohazardous Waste Management--the Nature of the Problem

Biohazardous wastes are discarded materials which contain pathogenic agents which--because of their type, concentration or quantity--may cause disease in persons or animals exposed to the material. For infection to occur, not only must a virulent pathogen be present, but there must also be a susceptible host, a route of exposure for transmission of the pathogen to the host and exposure to an infective dose (i.e., a sufficient amount of pathogens). Because of the variability inherent in these factors, it is difficult to quantify the relative danger presented by various types of

biohazardous waste. Therefore, management practices generally address preventing direct human contact with the waste material and treatment to destroy pathogenic agents.

Generators of biohazardous waste include health care facilities, academic and industrial research laboratories, the pharmaceutical industry, veterinary hospitals and the food, drug and cosmetic industries. Hospitals are the largest individual generators of biohazardous waste, producing perhaps 10 to 40 pounds per patient per day. Much of the waste stream consists of disposable items such as petri dishes, bottles, bedding, etc.

Studies have indicated that as little as 25 to 30% of the waste stream from a hospital need be considered biohazardous, and that if this portion can be kept segregated, then there is no need to treat the entire waste stream as contaminated. Opinions vary, however, as to how much of a hospital's waste stream should be considered to be biohazardous. The decision is generally up to the infection control staff and involves an assessment of the relative degree of risk posed by the various types of waste material. Clearly biohazardous waste streams include live cultures of pathogenic organisms from laboratories and materials which have come into direct contact with patients in operating rooms and isolation units. The hazardous nature of waste materials such as bedding, eating utensils, etc., is less clear.

A number of common infection control problems have affected hospitals and health care facilities in the past and have provided the impetus for stricter control measures. These include:

1. Inadequate segregation of biohazardous wastes from other solid wastes. In the past, many health care facilities have combined all waste materials for convenience in handling. This magnifies the infection control problem by contaminating the entire waste stream. This problem is perhaps best exemplified by the common practice of combining biohazardous waste and other solid wastes in compactor trucks for transport to an offsite disposal facility.

2. Inadequate measures to protect personnel. Prior to disposal, biohazardous waste must generally be moved from the point of generation within a facility to a location where it is stored until disposal can occur. If the waste material is not properly packaged or is

not stored in a secure area, exposure of personnel and others to infectious agents may occur.

3. Inadequate disposal methods. In general, biohazardous waste is disposed of by grinding to sewers, sterilization, incineration and landfill. Grinding to sewers is becoming less and less prevalent due to concerns over personnel exposure and the need for at least secondary sewage treatment to destroy pathogenic organisms. Sterilization and incineration are both effective treatment techniques which can result in complete destruction of pathogenic organisms if accomplished with appropriate equipment operated by trained technicians following rigidly enforced procedures. Under anything less than these optimal conditions, however, the effectiveness of sterilization and incineration is less than complete; one study estimated that over 75% of hospital incinerators are inadequate for biohazardous waste treatment. Finally, disposal of biohazardous waste to landfill holds the potential of exposing refuse workers to infectious agents during the landfilling process and of exposing the general population through water run-off, leaching, and vectors and vermin.

California's Biohazardous Waste Management Program

Concern over the public health impacts of improper management of biohazardous wastes culminated in the passage of SB 1482 (Doolittle) in 1982. The bill declared infectious waste to be hazardous and mandated the adoption of emergency regulations by the State Department of Health Services. Major highlights of the regulations, which were adopted in final form in late 1984, include the following:

1. Generators are limited in the amount of time that they can store biohazardous waste and are required to segregate biohazardous and nonhazardous waste streams. Double red bags must be used for waste containment and must be stored in secure containers or enclosures.

2. Compactors or grinders cannot be used for biohazardous waste handling.

3. Registered hazardous waste haulers must be utilized to transport biohazardous waste to offsite disposal facilities.

4. Restrictions and conditions are placed on sewering, sterilizing and landfilling of biohazardous waste.

5. Protective gear requirements are specified for persons involved in loading and unloading biohazardous waste from transport vehicles.

6. Hazardous waste facility permits are required for offsite incineration facilities.

Enforcement of the new regulations is split between the State Department of Health Services and local health authorities. In general, actual enforcement efforts have been lax but would appear to be gaining momentum as authorities gain experience and knowledge. Enforcement is hampered, however, by unanswered questions regarding the applicability to biohazardous waste of hazardous waste management regulations intended to regulate chemical hazardous waste.

Successful Strategies for Compliance

Compliance with the new State regulations and avoidance of infection problems can be achieved through a comprehensive strategy of internal management and careful selection of final disposal options. American Environmental Management Corporation (AEMC) has developed considerable experience in assisting generators of biohazardous waste in meeting their new responsibilities. The major points to be considered include the following:

1. Development of an internal strategy for segregation of waste streams to minimize the total amount of waste material which must be managed as biohazardous. Often, an educational program involving infection control, housekeeping and other relevant personnel must be undertaken.

2. Development of an internal collection system which maximizes convenience and minimizes the potential for exposure of personnel to biohazardous waste. To address this need, AEMC has developed a rigid wall collection and packaging system for convenient placement within the facility.

3. Provision of a secure storage area for containerized biohazardous waste. Because storage space is often limited, weatherproof lockable storage containers for outside storage are useful.

4. Treatment of biohazardous waste by sterilization, incineration or other effective method prior to disposal of residues to landfill. Often, improved procedures for treatment are necessary to ensure effectiveness.

5. Where treatment at the facility cannot be accomplished, biohazardous waste must be transported to an offsite facility by a licensed hazardous waste hauler who is insured, trained, and operates in compliance with federal and state requirements. AEMC provides trained personnel and fully enclosed vans for this purpose.

6. Disposal of biohazardous waste in an offsite landfill or incineration facility which is operated in compliance with local, state and federal regulations. Certain types of biohazardous waste cannot be legally disposed of in landfills. These restrictions, coupled with continuing concerns regarding the effectiveness of landfills for long-term secure disposal, indicate that incineration is the most effective technique for disposal of infectious waste. AEMC is in the process of constructing an offsite, state-of-the-art incineration facility to meet the needs of generators of biohazardous waste who must use a commercial disposal facility.

Careful consideration of the above factors and timely management decisions will lead to a biohazardous waste management program which minimizes the potential for human exposure and resulting liabilities. The most effective program is one which is ingrained into standard operating procedures and becomes "second nature" to those who are expected to use it. Because of this, education and awareness are doubtlessly the most important factors to be addressed.

STORAGE AND LEAK REMEDIATION

ALTERNATIVE APPROACHES TO COMPLIANCE WITH UNDERGROUND STORAGE TANK REGULATIONS

BY

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PLEASANT HILL, CALIFORNIA

Presented at HAZMACON '85, April 25, 1985

In 1984, the State of California adopted two laws aimed at regulating underground storage of hazardous substances to protect public healtn and scarce groundwater resources: Assembly Bill (AB) 1362 or the Sher Bill AB 2013 or Cortese Bill. The Cortese Bill requires registration of underground storage facilities by July 1, 1, including pits, ponds, sumps, and lagoons if below ground surface. AB 1362 creates a regulatory program for existing underground tanks to have permits and adequate leak detection systems to operate and performance standards for new tanks.

The state law of articular concern to industries especially to the petroleum industry is AB 1362 because of its numerous requirements and financial effect. It is estimated that there are over 10,000 underground storage tanks for petroleum products based on the result of the tank registration program. Present estimates of underground storage facilities is given below.

STATE UNDERGROUND STORAGE FACILITIES REGISTRATION[a]

Type	Estimated number registered	Percent of total
Motor vehicle fuel	112,200	67
Farm motor vehicle fuel	25,100	15
Total other type tank	19,400	12
Sumps	7,200	4
Pits	1,900	1
Other type strctures	1,700	1
Total	167,500	100

[a]Source: State Water Resources Control Board, April 15.

There are numerous local regulations already in effect to implement the state law which may be more stringent and must be followed within the local agencies' jurisdictions. These local regulations may vary from community to community, however, all must meet the minimum intent of the state law. Each local agency designated to implement the regulatory program will be responsible for issuing permits, inspection for compliance with construction standards, and monitorig and review of unauthorized release.

With the proposed state regulations, it is necessary to understand the implications of the overall regulatory program and how to comply with the differing regulations of various local governments. This paper is intended to provide an overview of the state and local regulations, and the alternative approaches to compliance considering:

1. Management and administration of the overall program.

2. Alternative methods and systems for leak detection and monitoring.

3. Cost of installation and monitoring of leak detection systems.

4. Factors to evaluate in selecting systems.

5. Recent experiences in program implementation.

6. Addressing any site contamination or unauthorized release.

An overview of the 1984 Amendments to the Resource Conservation and Recovery Act (RCRA) and its implication on state and local programs is also discussed.

<u>Overview of Proposed State Regulations</u>

On January 18, 1985, the State Water Resources Control Board published the draft reglations to implement AB 1362. The regulations will have to be approved by the Office of Administrative Law (OAL) before it can be enforced. The major elements of regulations are:

1. <u>New Underground Tanks</u>. Performance standards for construction of new tanks requires secondary containment, continuous monitoring of annular space, and tigetness testing prior operation.

2. <u>Existing Underground Tanks</u>. Standards and regulations for existing tanks are intended to detect unauthorized release before groundwater is affected. There are eight alternatives proposed with specific provisions as to its application.

3. <u>Reporting Releases</u>. This section of the regulations provides the proedures and requirements for reporting unauthorized release and defines specific procedures for recorded and reportable unauthorized release.

4. <u>Repair Standards</u>. Provisions under this section include certification and testing of repaired tanks and acceptable standards for repairing leaking tanks.

5. <u>Closure Requirments</u>. Regulations for temporary and permanent closures are provided in this section including variances

6. <u>Permitting and Reporting</u>. This section provides the permitting and reporting procedures and requirements. Local agencies authorized to administer the program will issue the permits as well as conduct the required periodic inspection of permitted facilities.

Once the state regulation is approved by OAL and becomes effective, local regulations must be at least as stringent. Many of the local governments are waiting for approval of state regulations before each will adopt and implement an underground storage tank regulatory program. Those local agencies with on-going programs prior to January 1, 1984, can continue to enforce their regulations; however, some local agencies' regulations may have to be revised to comply with the minimum requirements of the state regulations.

<u>General Approach to Program Compliance</u>

Although various local regulations may vary to some degree, there is a basic approach that can be implemented for overall program compliance. This approach, is generally an unerground tank management program that can or should be used as a preventive program to determine the integrity of the tank in order to reduce the risk of any unauthorized release.

1. Inventory existing tanks to determine the age and materials of construction. The state tank registration form provides the necessary information.

2. Test tanks and evaluate conditions. This is particularly important for aged tanks that are not protected against corrosion.

3. Determine tanks to replace with new tank standards based on the results of the first two steps.

4. Prepare managemet plan, permit application, and any disclosure statment required by local agencies.

5. Evaluate alternative leak detection/monitoring system for existing tanks that will not be replaced.

6. With approval or concurrence from local agencies, install monitoring system or new tanks.

7. Monitor the tanks and maintain records as required and if necessary, conduct tightness test periodically.

In general, this suggested approach applies to most underground storage facilities, more so for motor vehicle fuel storage tanks in service stations. Variations to this approach will depend on the number and locations of installations, cost factors, the hazardous sstance being store, and compliance schedule.

Proposed Monitoring System Alternatives for Existing Tanks

The proposed state regulations provide alternatives for monitoring existing tanks. Each alternative has specific provisions for applications and should be carefully evaluated in selecting the montoring system to install. The alternatives monitoring systems to consider are:

Method	Monitoring/frequency
1. Tank testing (precision)	Monthly
2. Vadose zone monitoring/	Daily/continuous
Groundwater monitoring/	Semi-annual
Soils analysis	Once
3. Vadose zone monitoring/	Dally/weekly
Soils analysis/	Once
Tank testing	Annually
4. Groundwater monitoring/	Monthly
Soils analysis	Once
5. Inventory reconciliation/	Daily
Tank testing (precision)/	Annually
Pipeline leak detectors	Continuous
6. Inventory reconciliation/	Daily
Tank testing (precision)/	Annually
Pipeline leak detectors/	Continuous
Soils analysis/	Once
Vadose or groundwater	Variable
7. Tank gauging/	Weekly
Tank testing	Annually
8. Tank testing/	Annually
Inventory reconciliation	Daily
of tank gauging	Daily/weekly
9. Other technology	--

Reference should be made to the state regulations for specific provisions on the applicability of each alternative. Local

agencies should also be consulted as to which of the alternatives are acceptable or preferred within their jurisdictions.

In general, the varius proposed alternatives to comply with the regulations fall under one of these categories:

1. Monitoring system for existing tanks using a combination of monitoring wells, leak detection devices, and inventory reconciliation or stock control.

2. Tank replacement of existing tank to conform with performance standards for new tank construction.

3. Periodic tank testing and other preventive measures to reduce the risk of structural failure and unauthorized release.

The first two categories appear to be the most acceptable alternatives (to state and local agencies) to meet the intent of law.

Monitoring Techniques

An effective monitoring program must incorporate the appropriate leak detection device and monitoring technique if it is to be the selected compliance approach for existing tanks. Site-specific devices and techniques must not only be compatible with the selected approach and underground facilities, but most importantly, it must detect any unauthorized release as early as possible. The technologies currently available for leak detection and monitoring are classified under the following applications.

1. Saturated Zone (Groundwater) Monitoring--Samples can be periodically collected using a bailer and analyzed on site or in a laboratory for any leaking product. Continuous monitoring devices are also available to detect any product release.

2. Unsaturated Zone (Vadose) Monitoring--Potential leaks in unsaturated zone can be periodically or continuously monitored using Various types of techniques. For periodic monitoring, samples can be collected and analyzed on the field using portable hydrocarbon analyzer or in the laboratory using gas chromatography/mass spectrophotometer (GC/M). Continuous monitoring uses sensors either a vapor or gas analyzer, thermal conductivity sensors, or electrical resistivity sensors.

3. Leak Detectors--These types of monitoring devices are available either as an internal or external system. Internal detectors include level sensors for inventory

reconciliation and vapor sensors for double-walled tanks. External systems are similar to devices used for saturated and unsaturated zone monitoring.

4. Tank Tightness Test--Methods currently preferred is the precision test wich can detect leak as low as 0.05 gallons per hour. Other techniques available are hydrostatic, vacuum, and presuure testing.

In selecting the monitoring system and techniques to be used, consideration must be given to several factors including:

1. Effectiveness and performance standards.
2. Sensitivity detection level required.
3. Cost of the system--initial and annual costs.
4. Condition of the tank--risk of failure.
5. Groundwater and subsurface conditions.
6. Frequency and cost of monitoring and analysis.

In addition to the above considerations, local agency concurrence must also be obtained in selecting the specific monitoring program to implement. Variations in local regulations will require close communication and cooperation with responsible agencies to ensure compliance.

Addressing Fuel Leaks

In implementing the selected monitoring program, it is possible that past and on-going leaks may be encountered. The San Francisco Regional Water Quality Control Board has issued a draft staff guideline for addressing fuel leaks. The draft guideline is under public review and will be used primarily as a guide by the regional board staff. The four categories presented in the draft guidelines are:

1. Suspected leak.
2. Confirmed release.
3. Fuel case.
4. Toxics case.

The draft guideline provides criteria for classifying unauthorized release and the suggested regional board action to address each one. The decision criteria to consider in classifying fuel leaks are:

1. Tank tightness test.
2. Inventory control (product loss).
3. Groundwater and/or vapor monitoring results.
4. Soil and/or groundwater contamination.

It is expected that the staff guidelines will be finalized in July or August 1985.

1984 Resource Conservation and Recovery Act (RCRA) Amendments

One of the most significant amendments to the Resource Conservation and Recovery Act in 1984 is the regulation of underground storage tanks. This federal regulations will cover similar areas already regulated under California AB 1362. However, the U.S. Environmental Protection Agency (EPA) is now authorized to regulate underground storage tanks nationwide. The general provisions of the federal regulations include:

1. Notification requirement which will require all owners/operators of underground storage faiiities to notify the state agency designed by the Governor within 18 months of the date of enactment.

2. Release detection, prevention, and correction requirements will provide standards and regulations for construction of new tanks and monitoring of existing tanks.

3. State program authorization providing each state the responsibility to adopt and enforce equally stringent regulations.

4. Inspections, monitoring, and testing requirements will provide the procedures and requirements for testing, reporting, and recordkeeping.

5. Federal enforcement defines the authority of EPA to assess penalties for compliance or violations.

Based on comments received from EPA, it is expected that the final federal regulations will resemble as close as possible state regulations currently in effect within the intent of the 1984 RCRA amendments.

Program Approach

Because of the numerous and differing regulations in California, coupled with the proposed federal regulations on underground storage tanks for hazardous substances, it is necessary to develop an approach to manage and administer the program for compliance. This is particularly important for major petroleum companies or other companies with numerous underground storage tanks in several governmental jurisdictions. Factors to consider in developing a program approach are:

1. Compliance with regulatory agency requirements and schedule.

2. Communication link with regulatory agencies.

3. Effective coordination of various activities, personnel, and regulatory agencies.

4. Flexibility in approach to adapt to various regulations and changing requirements.

5. Objectivity in approach particularly in evaluating alternatives versus cost.

6. On-going management and implementation of the monitoring program including reporting and system maintenance.

7. Number and location of facilities.

8. Availability of in-house personnel.

9. Overall cost of the program.

Each company should assess these factors in detail in developing a specific program apprach. The management approach can vary from total in-house staff management to hiring a consultant to oversee the entire program.

The key cost factors to consider in developing the approach and deciding who should manage the program are:

1. Program administration/management including tank inventory and registration, preparation of plans and permit applications and coordination with regulatory agencies.

2. Installation of monitoring system including cost of system, supervision of installation and analytical services.

3. Replacement of tanks includes cost of new tanks and any required analytical services hydrogeological investigation and cleanup of site contamination.

4. Long-term monitoring including collection and analysis of samples either on-site or in the laboratory.

In spite of the numerous state and local regulations, a program approach can be developed to comply with these differing requirements. There are, however, several areas where technical evaluation and judgment are necessary to address specific requirements and site-specific conditions. Working closely with regulatory agencies is equally important in effectively managing the program and complying with specific local requirements.

AN INVESTIGATION OF THE EFFECTIVENESS OF VADOSE ZONE MONITORING DEVICES IN IDENTIFYING LEAKS IN UNDERGROUND STORAGE TANKS

Reinhard Hanselka
Advanced Industrial Designs, Inc.

REGULATORY BACKGROUND

Underground tanks used for the storage of hazardous materials are covered by an emerging body of regulation being implemented at the Federal, State, and - in some instances - local levels.

The objective of those regulations is to reduce the threat to the nation's groundwater supplies and to minimize other hazards posed by leaking tanks.

In 1976 Congress enacted the Rescource Conservation and Recovery Act (RCRA) covering the storage, handling, and disposal of hazardous materials of all descriptions.

When RCRA was amended in 1984, the amendments included a major new program - Subtitle 1 - to control the release of hazardous materials, including petroleum products, from underground storage tanks.

That program:

1. Requires the States by May 1985 to designate an agency or agencies to receive notification from tank owners.

2. Requires tank owners by May 1986 to notify the designated agency or agencies of the location and use of underground storage tanks.

3. Prohibits the installation of certain new tanks beginning in May 1985 and until new EPA tank reguations are issued.

4. Requires the EPA to issue regulations for LEAK DETECTION, preventive, and corrective action for all new and existing tanks, and for design and installation of all tanks used for petroleum products by May 1987, and other products by November 1987.

5. Provides for approval of State programs to operate in lieu of Federal programs.

6. Requires the EPA to prepare several reports to Congress covering underground tanks.

Thus, the framework has been established for nationwide regulations covering underground tanks including those regulations created and implemented by the States.

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VAPOR MONITORING SYSTEM....

Because the Federal government has been slow in acting on the underground tank problem and because of the severity of the problem in certain locales, some states, including California, already had taken steps to regulate underground tanks by the time the 1984 RCRA amendments were enacted.

California's primary legislation exists in the form of Sher Bill AB 1352 which includes provisions that parallel those in RCRA but specifies earlier compliance dates.

The Sher Bill also provides for local regulation of underground tanks as an alternative to compliance with the State regulations. A number of communities have chosen that option and currently have regulations in place.

While the regulations being implemented at various levels throughout the nation vary in detail, all include provisions calling for the registration of tanks, the implementation of design and installation standards, and a requirement for some type of leak monitoring system or program.

THE INVESTIGATION

The inclusion of monitoring requirements in the various regulations served to focus considerable attention on the need for equipment that would satisfy objectives of the regulations.

Two options were available:

1. The adaptation of existing systems and techniques.

2. The development of new technologies.

Genelco, Inc. located in Dallas, Texas was one of the companies considering the marketing of a system that could be installed to bring tank owners into comliance with the new regulations.

After surveying the systems and techniques already in existence and exploring various new technologies, the company elected to pursue development of a new type of system.

Preliminary research suggested that a vapor sensing system offered the greatest potential.

Although there was strong evidence to support the theory that leaks could be identified by monitoring the soil surrounding

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a buried tank for the presence of vapors given off by the leaking material, the concept had not been proven in practice.

Advanced Industrial Designs, Inc. was contracted to serve as a consultant in the investigation.

In the course of that investigation and testing of a prototype system, it was concluded that an aspirated vapor sensing device could provide the superior leak detection capabilities required to satisfy the objectives of the regulations.

VAPOR MONITORING THEORY AND METHODOLOGY

The applicability of vapor monitoring as a technique for identifying leaks is keyed to the volitility and composition of the material contained in the storage vessel.

When as a leak occurs in an underground tank used for the storage of such materials, the natural dispersion of heavy vapors has been demonstrated to be downward in the form of a conical plume and that those vapors will move rapidly through the material in which the tank is buried.

The rapid dispersion of the vapors is a key factor in the preference of vapor monitoring as compared to other methods.

Since the vapor will move up to fifty times more quickly than the migrating liquid, vapor sensing can provide the response time needed to take corrective action before the leaking liquids can reach groundwater supplies.

Vapor sensing can be performed using two techniques:

1. Passive sensing which involves the location of a sensor or probe at a point in an area projected to be within the conical plume of a leak.

2. Aspirated sensing which involves the creation of a low pressure zone at a probe/sensor. Such a low pressure zone will serve to attract vapors resulting in a system that actively searches for leaking materials rather than relying on their natural migration.

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Of the two techniques, aspirated sensing is preferred since probe/sensor placement is not critical to the timely identification of a leak.

SYSTEM DESIGN

To determine the usefulness of vapor sensing as a means of detecting leaks, a prototype aspirated system was constructed.

Although the system was built as a prototype, it incorporated all the features anticipated to be required in a production configuration of the device.

The key elements in the system included the following items all of which were packaged in a single module.

(See Figure 1: Operating Components)

1. An aspirator pump for the collection of vapors.
2. A bulk semiconductor vapor analyzer.
3. A manifold assembly with solenoid valves, providing a series of individually controlled ports allowing selective sampling at multiple locations.
4. A microprocessor to control all system operations.
5. A printer to provide full documentation of all operations.

External components included: probes consisting of nothing more than lengths of 1/2 inch i.d. PVC pipe with 0.01 inchs slots in the lower portion; a restrictor/filter assembly for each probe; and lengths of 1/4 inch i.d. tubing to connect the module the remote probes.

(See figure 2: Probe Diagram)

In operation, the system would sequentially and automatically draw air samples from the probes which would be inserted into the soil at the site to be monitored. The samples would be carried back to the module by the small diameter tubes and be analyzed in the module to determine their vapor content. The results would be documented by the printer.

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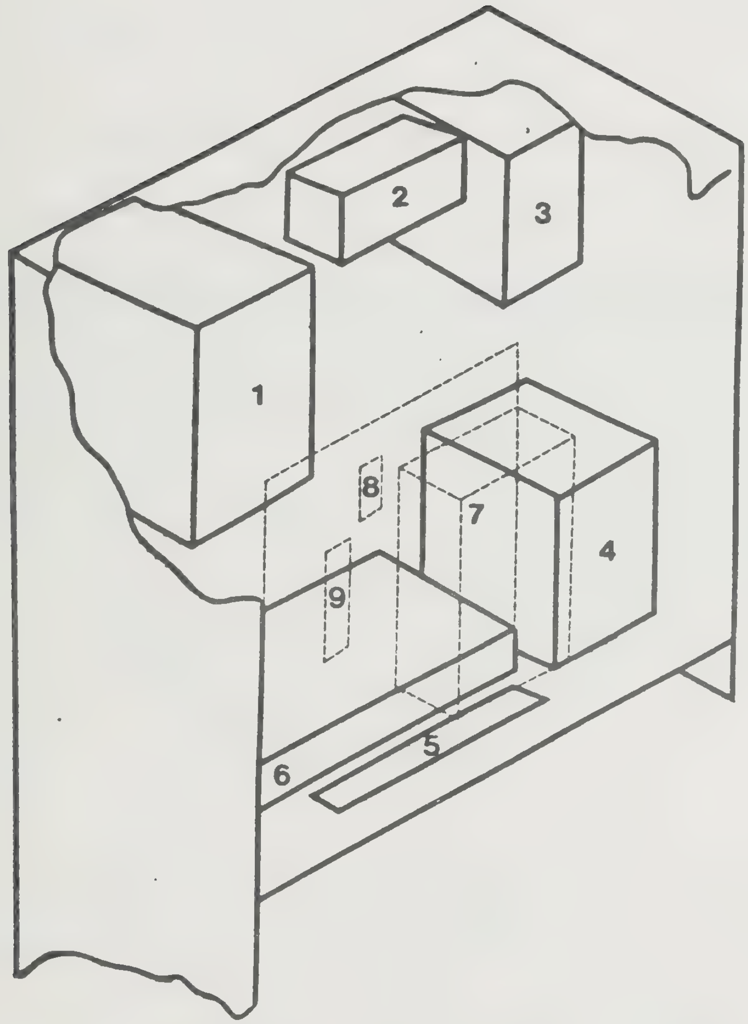
FIGURE 1: OPERATING COMPONENTS



1. Transformer

2. Aspirator Pump

3. Sensor

4. Accumulator Manifold

5. Terminal Block

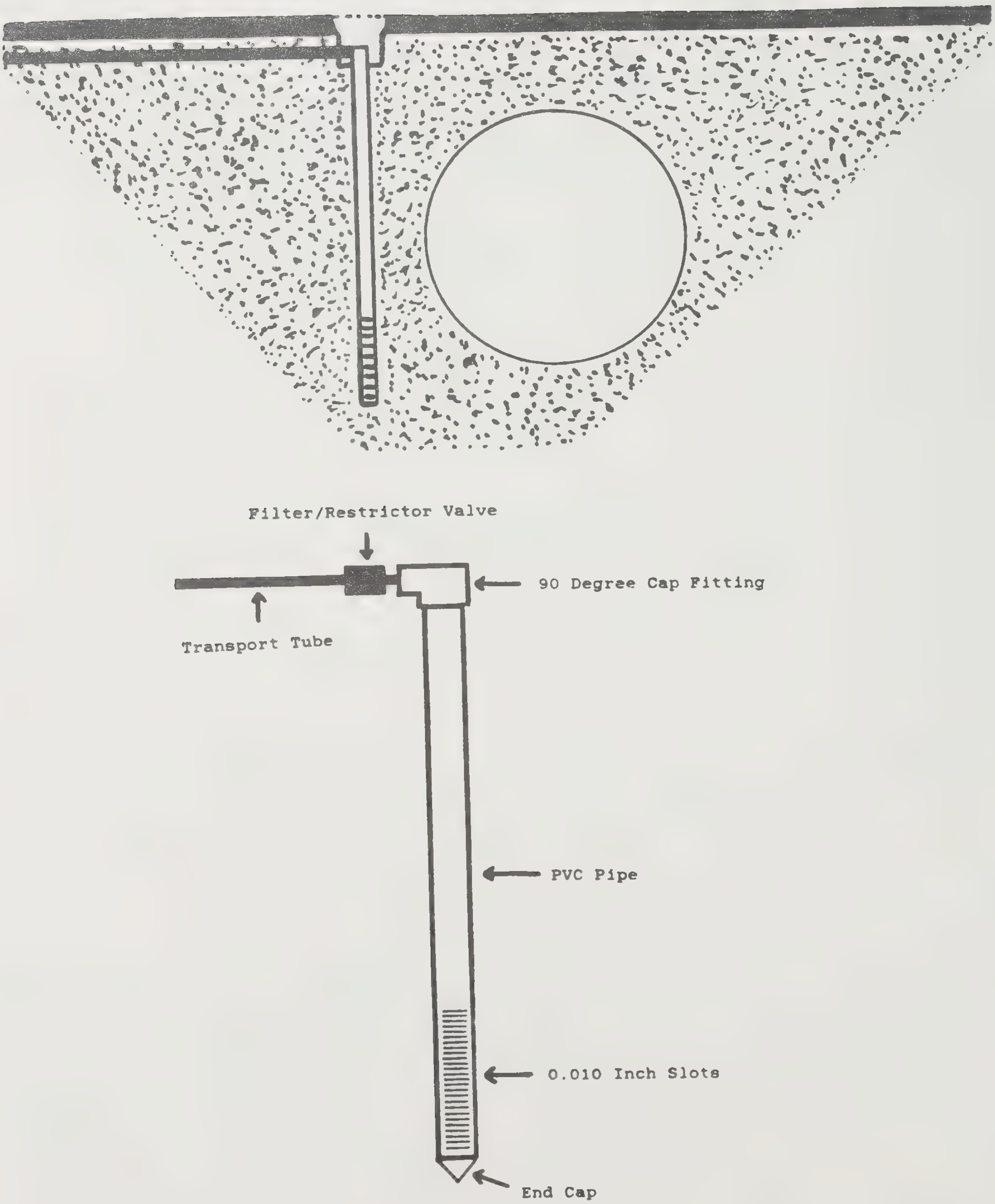
6. Valve Manifold

7. Printer (on circuit board)

8. 4 Bit Dip Switch (on circuit board)

9. 8 Bit Dip Switch (on circuit board)

FIGURE 2 : PROBE DIA



LABORATORY TEST OF PROTOTYPE

Following its completion, the prototype was turned over to Advanced Industrial Designs for laboratory testing.

To perform that testing a 4 ft. by 1 ft. by 1 ft. plywood box was constructed.

The box was then filled with a mixture of equal amounts of sand and clay to approximate a typical backfill condition.

Twelve probes were inserted into the sand,clay mixture, along the full length of the box.

the operation of the system was tested by placing 10 ml of a test material solution on a pad on top of the soil,clay mixture. The test material would migrate through the pad and into the mixture.

The following materials were tested:

1. Acetone
2. Gasoline (regular)
3. Gasoline (unleaded)
4. Methylene Chloride
5. Tri-chloroethylene (TCE)

The soil was renewed after each chemical test

All tests were performed at soil moisture saturation levels of 15 and 50 percent.

In every instance, the documented test results showed that the system would identify the rapid migration of the vapors through the soil,clay mixture and would register their intensity.

As a result, the lab tests were judged to have demonstrated the functionality of the prototype system and provided initial evidence of the applicability of vapor monitoring as a valid method of leak detection.

(See Report 1: Genelco Soil Sentry)

INITIAL FIELD TEST

Following the successful lab testing of the device, permission

was obtained by the owners to perform a field test at an abandoned service station in Palo Alto, California.

The site was certified by an independent consultant to contain only minimal hydrocarbon levels in core and water samples taken in to establish site conditions.

The initial plan called for the injection of a a maximum of 64 ounces of a non-hazardous test material into the soil to simulate a leak. That plan was rejected by local officials.

At the time, however, a contractor was working at the site to test the tanks. During the process of testing, a check valve was removed and less than one gallon of fuel was inadvertently discharged.

In this situation the closest sampling probe (Probe 2) was located approximately 9 ft. from the point of the release. The system detected vapors at that probe within about twenty minutes of the time of the spill.

The next closest probe (Probe 1) was located approximately 20 ft. from the spill. Vapors were detected at that point approximately 24 hours later and the recorded concentrations were lower than at Probe 2.

Approximately two weeks after the incident, the vapor levels as observed by the system had decreased to the original background levels documented prior to the spill. Thus it appeared that the system could not only detect a spill but could distinguish, over a period of time, whether the release of material was continuing or was transient in nature.

A third port in use (port 3) was installed in an existing water well. On a previous occasion another spill resulted in a small amount of fuel entering the water system. The system detected the light film of fuel on the water in the well. When the water was analyzed it show a concentration of approximately 80 ppm fuel in solution.

A water monitoring device in place at the well proved unable to detect the same concentration of fuel.

The test provided further evidence of the system's value as a leak detection device and served to emphasize its utility in the early detection of leaks as well as in documenting changing vapor conditions at the site.

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(See Report 2: Capabilities of Soil Sentry Underground Tank Leak Detection Under Field Test Conditions)

ADDITIONAL TESTING

Because the field test was performed under circumstances that provided less than the desired degree of control, the determination was made to conduct a third test of the system for purposes of further verification.

In this test, a truck bed was filled with approximately 7.7. yards of standard sand fill typical of that used in underground tank installations and a polyvinyl blanket was spread over the top to simulate the asphalt/concrete pad normally found over installed tanks.

Probes were installed at 7 sampling locations throughout the fill material.

Common low lead gasoline was leaked into the fill material at a point at one end, center of the truck bed.

The leak rate selected was 180 ml per hour, less than the 0.05 gallon per hour standard commonly referred to in most published standards.

The leak was allowed to continue for a 17 hours resulting in a total release of 2.74 liters of gasoline.

After 9 hours, the system identified vapors at two separate sampling locations 5 ft. from the release point.

After 19 hours vapor was detected at two sampling locations 9 ft. (the greatest test distance) from the release point.

Additionally, it was confirmed, through the positioning of sampling points at various depths, that the vapors did migrate to the bottom of the test bed.

Finally, continuance of the sampling over a total of 65 hours resulted in steadily diminishing vapor level readings, confirming again that a vapor monitoring system of the type tested could distinguish between a classic leak condition and a transient condition such as a spill.

(See Report 3: Los Angeles Soil Sentry Test)

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CONCLUSIONS

In three separate test conducted by different parties under widely varying conditions it was confirmed that an aspirated vapor type monitoring system can be expected to quickly and consistently detect leaks of vapor producing materials from underground storage tanks.

It was demonstrated that such a system with multiple probes can identify the probable location of a leak and track the migration of the leaking material.

It was further demonstrated that such a system can differentiate between a continuing leak and a vapor condition of a transient nature such as a spill.

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SOME TECHNICAL CONSIDERATIONS TO BE ADDRESSED WHEN DESIGNING A CLAY-LINER-CONTROLLED WASTE DISPOSAL SITE

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The construction of a waste disposal site or the enlargement of one in operation is an engineering endeavour. Such perception has been recognized only in recent years, however. The activity of properly disposing of wastes is more and more viewed as a part of the technological process used in a particular industrial unit. Accordingly, state agencies are involved in authorizing and permitting the proper construction of waste facilities. This is done through different regulations among which not the least important is the Subchapter 15, Discharge of Waste to Land of CAC, Title 23, Chapter 3. This document addresses all important problems raised by owners, operators and technicians who become involved in the construction, management or operation of a site, and people at the state, regional or local level with responsibilities in supervising the proper construction, management or operation of a site. Subchapter 15 is thus addressed to a large and seemingly diverse audience. In order to increase the efficiency of this document, permanent communication should be established between the writers of this document (and of others to come) and the readers who represent so many diverse groups. I

cannot think of another meeting which maintains the permanency of communication so alive as our Hazmacon.

In my presentation I will address three topics. Their understanding should be of value for professionals involved in the design of waste sites. I hope that my point of view on these issues will be intriguing and innovative.

First, I will raise the question of the flow characteristics of contaminant transport below and around a waste-disposal site. I will address this question by reasoning that unsaturated rather than saturated flow characteristics should often guide us when selecting a site. I will indicate computational procedures which can be used to estimate with a reasonable degree of safety the $K(\theta)$ function, the relationship between the moisture content and the hydraulic conductivity.

Second, I will present a point of view on clays as barriers, discussing their vulnerability when exposed to concentrated, aggressive chemical compounds. I will present a critique of testing procedures recommended to assess the clay/leachate compatibility.

Third, I will reason for a quantitative approach in assessing contaminant movement through soils, by emphasizing the use of numerical modeling. I will mention some limitations of such procedures.

Assessment of the contaminant transport properties: saturated versus unsaturated flow.

According to Subchapter 15 clay liners are expected to be characterized by permeabilities lower than 10^{-7} or 10^{-6} cm/s when constructed at a Class I or respectively Class II sites (Articles 3 and 4). These figures are to be obtained by determining the saturated (hydraulic) conductivity of soil elements sampled from the actual soil liner or soils intended to become part of the future liner.

If the analysis of microclimatic and local hydrologic data leads to the conclusion that the clay liner will be, during the operation of the site, in a state of high degree of saturation, then the saturated determination of the hydraulic conductivity is fully justified and reasonably conservative. In such cases (and even in drier environments) the suggestion that the unsaturated flow properties should be investigated, may - in general - be discarded as unnecessary.

The specifications for the "immediately underlain ... natural geologic material ..." described in Subsections 2531(b) and 2532(b) indicate the same figures as for clay liners. Since no additional explanation is provided it is to be assumed that here, like in the case of clay liners, the saturated flow characteristics should be assessed.

The underlying soil in moderately wet and drier climates, with a non-superficial groundwater and with a "reasonable" topography, will be as a rule in a reduced state of saturation. Such scenarios will be often found in the western part of the country where evaporation exceeds precipitation over extended periods. Consequently, the laboratory unsaturated flow transmission properties should be monitored and not the saturated one for what is generally called the underlying soil. In a recently published paper Keros Cartwright with the Illinois State Geological Survey, stated that "Unsaturated flow of groundwater has only recently been recognized as an important factor in contaminant transport by geologists and engineers engaged in waste-disposal work. The field of soil physics has made great progress in the past 20 years; however, little is known about this field by many practicing hydrogeologists", (Cartwright, 1984).

One may think of two reasons why our regulations do not require the determination of unsaturated flow characteristics: the fact that such determinations are extremely hard to be performed on a routine basis and, by determining the saturated hydraulic conductivity, one obtains a larger K-value and thus the assessment of the suitability of a particular site based on such data becomes a conservative one.

Let us explore some of the consequences of considering and testing saturated flow even though we know that such conditions will not prevail under our hypothetical waste-disposal site.

First, one needs to estimate the magnitude of the drop in permeability upon desaturation. If such an effect to say 50% saturation is to drop the K-saturated value by one order of magnitude or less, then the thought that we should test for saturated permeability can be looked upon as a prudent decision. If, however, the value of K at a relative saturation of 0.5 is 1000 times less than the K-saturation and if we intend to use this data in a dry environment, then our action may be called over-conservative.

Second, one should consider that although at saturation clays are undisputably less permeable than sandy soils, upon drainage and at the same degree of partial saturation the discrepancy between their K values may diminish considerably.

Figure 1, presents data from Elrick and Bowman (1964) and Gardner and Miklich (1962) quoted by Jackson, et al (1965) on the relationship between volumetric moisture content and the permeability (often called the $K(\Theta)$ function) for three loamy soils, (Jackson, et al., 1965). It is clearly shown that upon desaturation to around 0.5 the K-value drops in the Guelph soil to 1/4000 of the K-saturation value, in the Pachappa soil to 1/100 of it and in the Adelanto soil to 1/2000 of the

JACKSON, ET AL (1965)

Figure 1

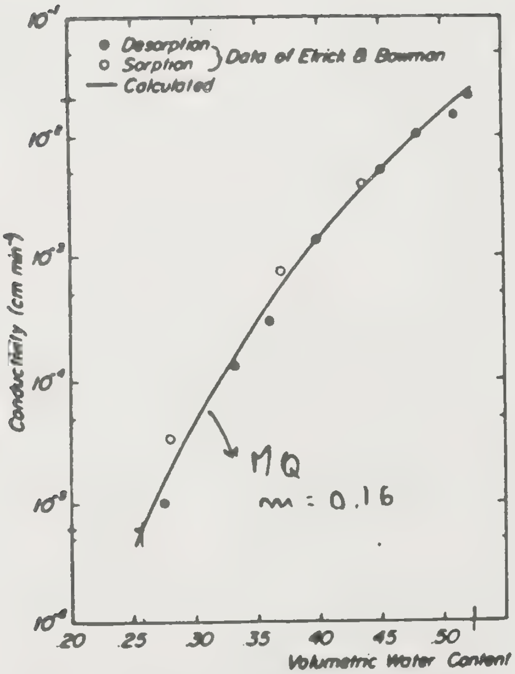


Fig. 4. Hydraulic conductivity of Guelph loam; the line was calculated from Figure 2 of *Elrick and Bowman* [1964] and the symbols are reproduced from their Figure 3.

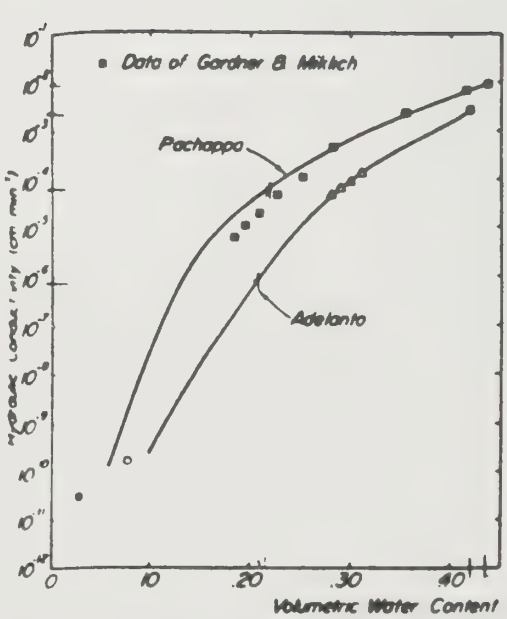


Fig. 6. Hydraulic conductivity of Adelanto loam and Pachappa loam, measured and calculated from characteristic curves.

K-saturation.

Kunze, et al (1968), partially using data from Kunze and Kirkham (1962), have presented the K(Θ) function for three heavy soils, (Kunze, et al, 1968). Their data are presented in Figure 2. It can be seen that the ratio of K-saturated to K at a degree of saturation of 50% is equal to 1000 for the silt loam, 3000 for the silty clay loam and 30,000 for the clay. If samples would have been prepared at a higher density the K-saturated values would have been much smaller (particularly for the clay soil) and consequently the above figures would have been lower.

Mualem and Klute presented in a recent paper a K(Θ) function for a dune sand (Mualem and Klute, 1984). It is presented in our Figure 3. The authors were intrigued by the drastic drop of the permeability from the saturation to 50% of it. The drop corresponds to a factor of 2000.

As a general conclusion to all these three figures one can expect for properly compacted soil specimens sampled in the vadoze zone, a ratio of K-saturated over K at 0.5 saturation between 100 and over 1000. The sandy soils are expected to be concentrated in the higher range and clay soils in the lower range. This means that the lower the degree of saturation, the smaller the well known difference in permeability between clays and sands. It should not come as a surprise that soils with clearly different textural characteristics (particle size distributions) will have

KUNZE ET AL (1968)

Figure 2

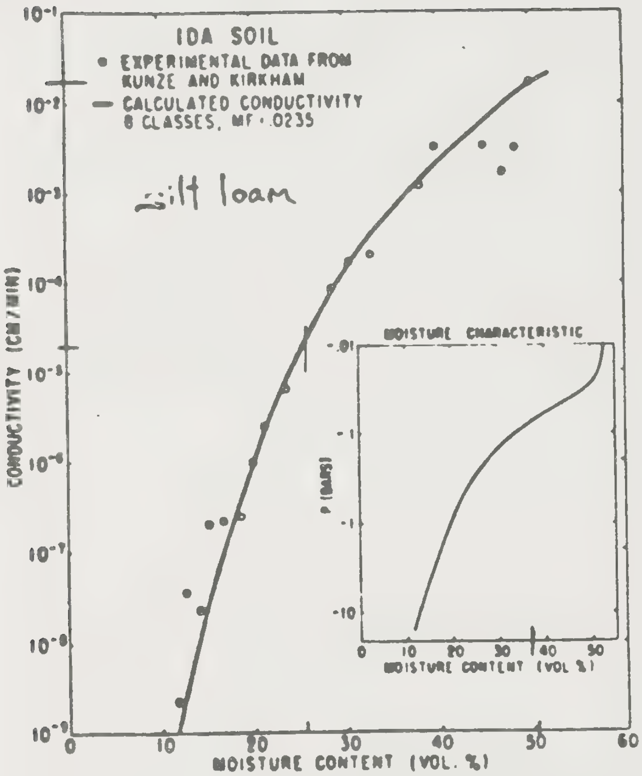


Fig. 4—Comparison of measured and calculated conductivity for Ida soil.

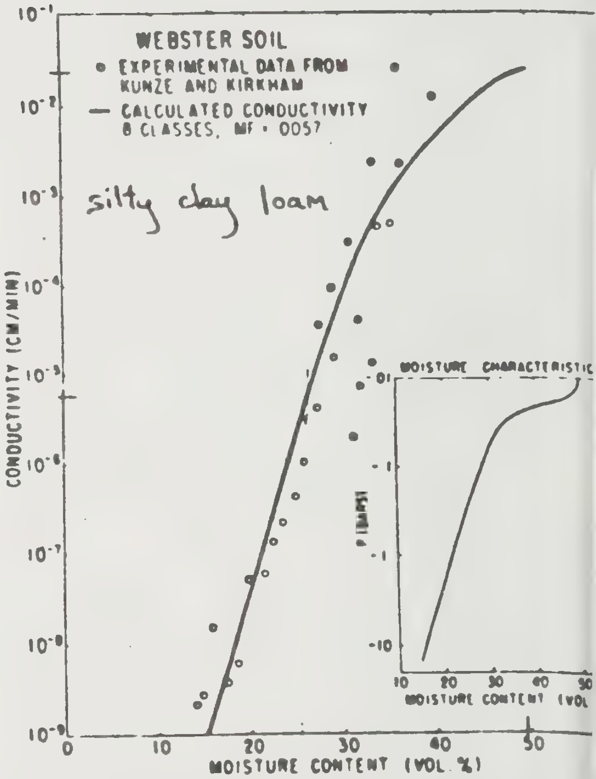
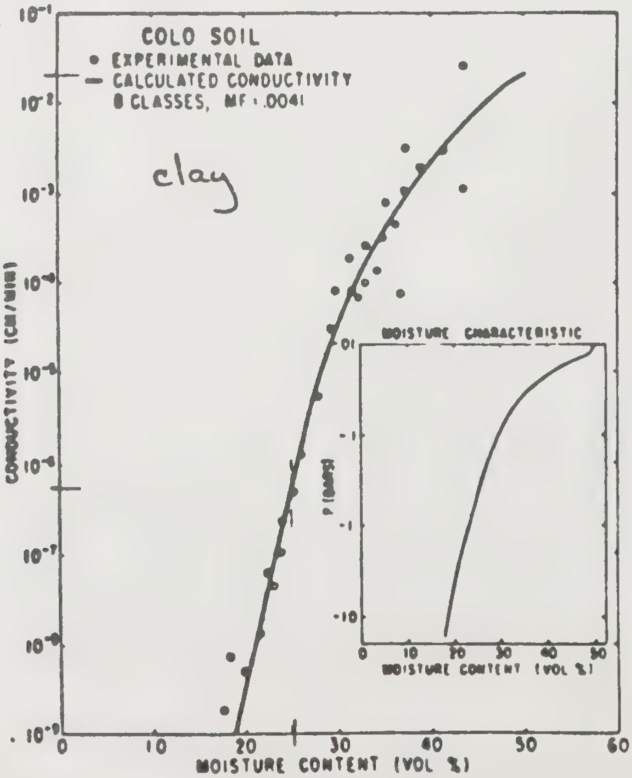


Fig 5—Comparison of measured and calculated conduct[ivity] for Webster soil.



[Fi]g. 6—Comparison of measured and calculated conductivity for Colo soil.

Figure 3

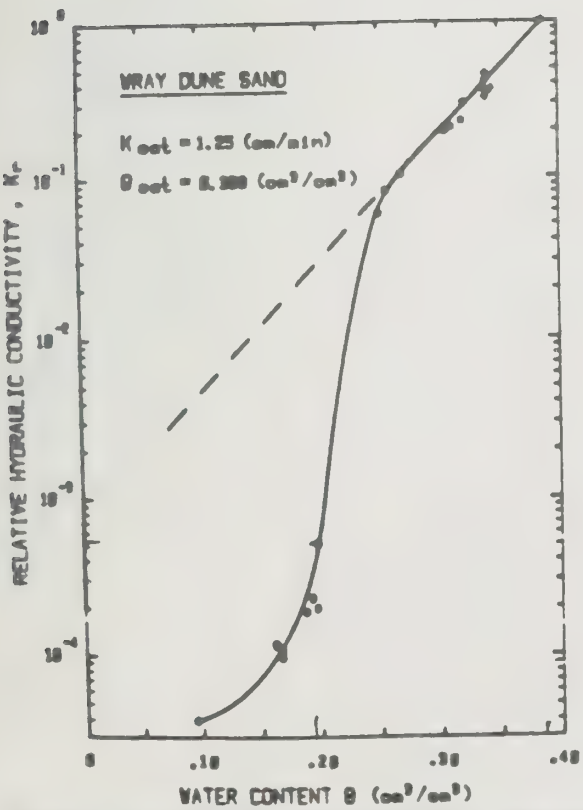


Fig. 9—Measured relative hydraulic conductivity vs. water content following the first drying process (stars), resaturation (pluses) and the main drying process (circles).

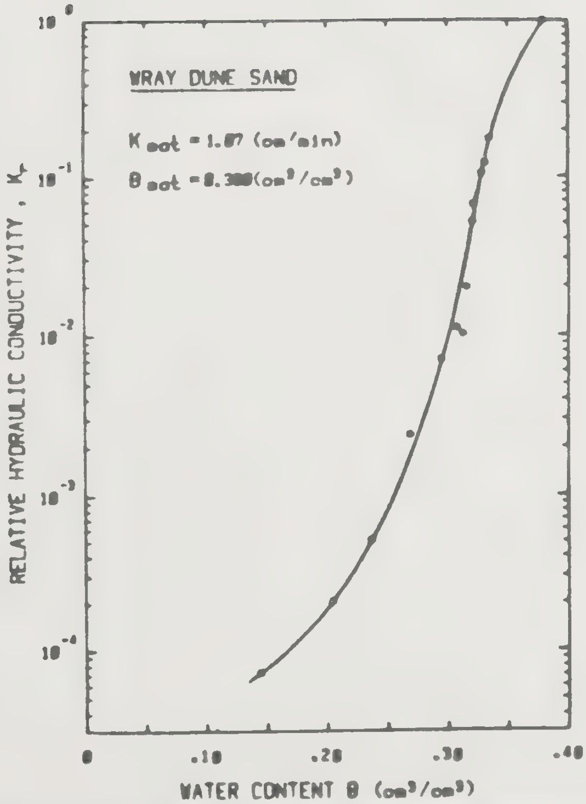


Fig. 11—Measured relative hydraulic conductivity vs. water content for the second pack of the Wray dune sand.

equal permeabilities at a particular moisture content. If that particular moisture corresponds to the prevailing moisture content characteristic for the soil in the field then both soils should be assigned the same ranking when judged as potential sites.

The fact that for very diverse soils the ratio K-saturation to K at 0.5 saturation is in the 10^2 range and that it depends on the textural composition, makes the use of K-saturated as a siting criteria, a relatively poor one.

As mentioned in the first part of this presentation the difficulties encountered when determining the unsaturated hydraulic conductivity are at times prohibitive. Klute made a comprehensive review of available procedures (Klute, 1972). He described in detail the steady state methods (both short and long column versions) and the many unsteady-state methods among which the outflow-inflow methods have acquired wide acceptance (short column - small increment, short column - large increment, Boltzmann transform, moment and vertical infiltration). Also in the group of unsteady-state methods are the instantaneous profile and the unit gradient - drainage methods. In a more recent comprehensive review of the subject Ragab, et al (1981) added the infiltration through crust and the hot air drying, to the repertoire of procedures. An ingenious procedure for determining the diffusivity function $D(\Theta)$ was presented by Miller and Bresler (1977). Mualem and Klute (1984) developed a procedure in which

the hysteresis phenomena are accounted for and which is much faster. Thus, one can say that substantial progress was made in the testing procedures used to determine the soil unsaturated hydraulic conductivity.

The importance of knowing the unsaturated soil hydraulic characteristics cannot be over-emphasized. Only by knowing them one can do quantitative analysis. Because of considerable difficulties in determining the K(Θ) function, attempts were made quite early to calculate rather than directly determine this function.

The computational procedures so far developed belong to two groups. The first one is based on a generalization of Kozeny's approach according to which the relative permeability is a power function of the effective saturation,

$$K_r = K/K_{sat} = S_e^{\alpha}$$

with

$$S_e = (\Theta - \Theta_r)/(\Theta_{sat} - \Theta_r)$$

where Θ and Θ_r are the actual and the residual water contents and S_e is the effective saturation. Mualem (1976) quotes Averjanov using this equation with an α = 3.5 while Irmay derived this

formulation theoretically with $\alpha = 3.0$.

A second group of relationships have obtained a larger popularity. They correspond to models which make all use of the relationship between the moisture content and the negative pore water pressure $\Psi(\Theta)$, the moisture characteristic curve. Childs and Collis-George (1950), Burdine (1953), Marshall (1958), Millington and Quirk (1961) and Kunze, et al (1968) have contributed to this group of models. A considerable effort was directed toward correlating measured with calculated $K(\Theta)$ functions. At times it became difficult to decide which one of the two is more trustworthy. Mualem (1976) also followed the Childs and Collis-George general model but he derived a more flexible mathematical formulation, which is,

$$K_r(\Theta) = S_e^n \left[\int_0^{\Theta} d\Theta/\Psi \Big/ \int_0^{\Theta_{sat}} d\Theta/\Psi \right]^2$$

When $\Psi(\Theta)$ is given in analytical form (for example using Brooks and Corey (1964) relationship),

$$S_e = (\Psi/\Psi_{cr})^{-\lambda}$$

Mualem's equation yields,

$$K_r(S_e) = S_e^{\,n+2+2/\lambda}$$

The "n" exponent is specific for each soil. It accounts for the

correlation between pores and for the flow path tortuosity.

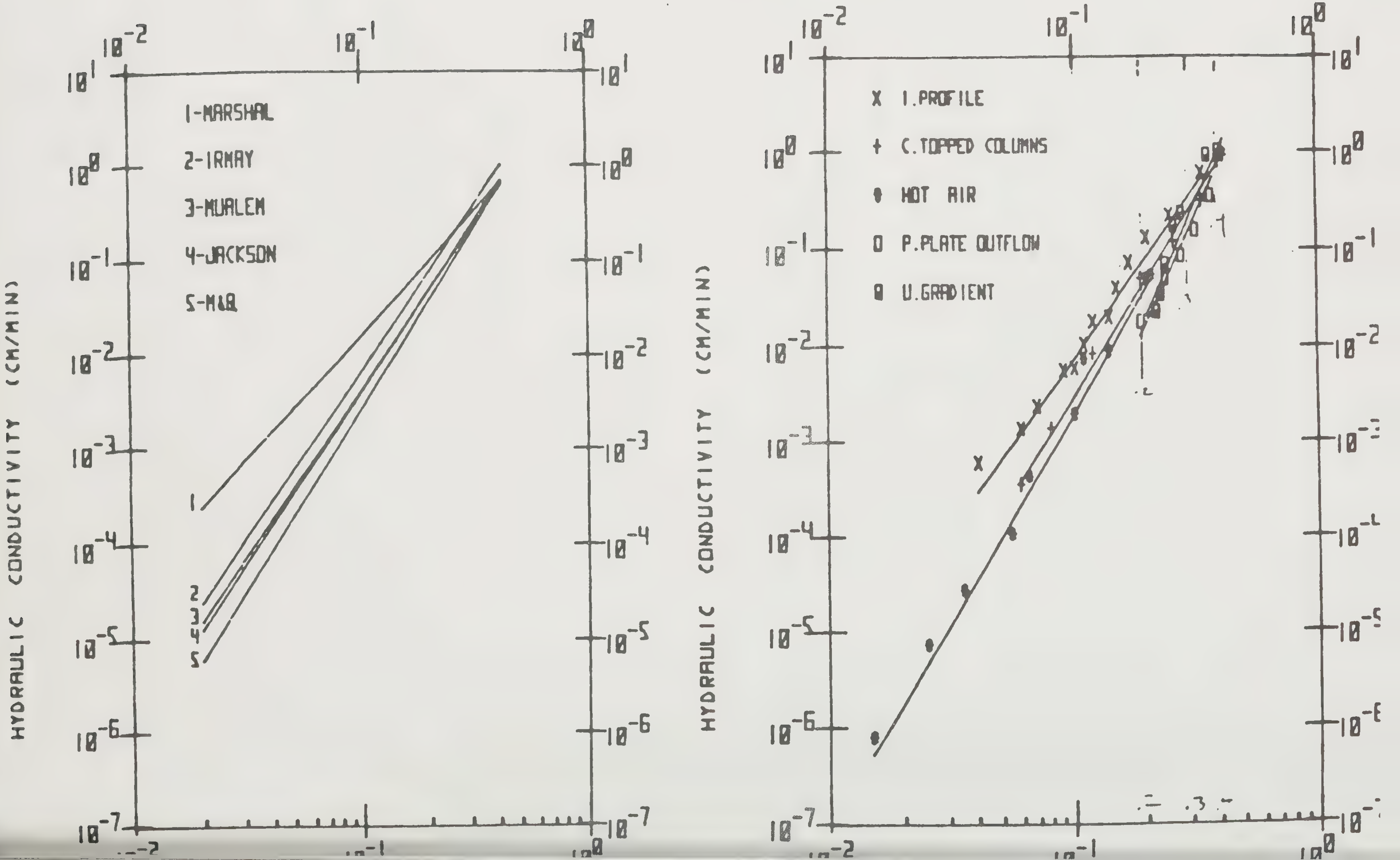
Considering the large variation of the hydraulic conductivity with the moisture content (as we have seen over three orders of magnitude when the moisture content drops to half of its saturation value), it would look futile to attempt to calculate this function. However, Nielsen, et al, (1960), Jackson, et al, (1965), Kunze, et al (1968), and Mualem (1976) have done such calculations and correlated them with measured values. Ragab, et al, (1981) correlated $K(\Theta)$ functions determined using five different procedures with three computational procedures (Irmay, Jackson and Mualem).

Figure 4 presents the measured $K(\Theta)$ function for a sand on the right and the calculated one on the left. There seem to be a considerable correlation between the two sets of data.

In this section I have underlined the need to account for the unsaturated solute flow characteristics, particularly for the western part of the country. I have also indicated computational procedures which are available to reasonably estimate the permeability of a particular soil as a function of its moisture

RAGAB ET AL (1981)

Figure 4



content. Although not rigorous such empirical calculations are a simple way to obtain data which subsequently can be used to quantitatively analyze the unsaturated plume dispersion, in time and space.

Clay chemical vulnerability. Clay/waste leachate compatibility.

Rather than listing the many papers which have attempted to prove that clays are vulnerable and thus degradable, one should make an attempt to understand how it all started. One should recall that in any introductory course of soil science the point is emphasized that unlike primary minerals, clays as secondary minerals are very reactive. Some 50 years ago research was generated which proved that some clays behave differently depending on the inorganic chemistry environment with which they are associated.

When our present problems of soil and groundwater contamination developed, considerable information had been accumulated in the field of soil science to prove that clays are chemically active and thus some of them could not be used as liners in some chemical environments. The task was then to identify which were the most sensitive clays (thus the most likely to change) and which were the most likely chemical compounds to induce such changes. We attempted to identify the "loosing" combinations rather than the "winning" ones. In retrospect, one should say

that this was a sound, conservative approach because it was meant to identify circumstances which had to be avoided in the practice of waste disposal.

In performing such a research program using what is being called the fixed-wall-permeameter procedure, neat organics were leached through short clay-soil columns and the outcome monitored. The overall conclusion of the said research effort was that many neat organic compounds are not compatible with some clay materials. In particular methanol and xylene increased significantly the saturated permeability of a smectite soil following the leaching of as little as one pore-volume of neat compound through the soil specimen, (Anderson, et al, 1982). The experimental techniques used are basically those described in our Subchapter 15, Appendix 1.

In a recent publication, Daniel and Liljestrand (1984) have gathered practically all data available on the subject of clay-soil permeability when tested with a large number of natural or synthetic leachates. One of their many conclusions was that "... dilute organics do not adversely affect the permeability of natural earth liners".

In compatibility studies there is agreement on the opinion that the most reactive clay mineral in the group of those widespread,

is the montmorillonite. An example of a montmorillonite from Crook County, Wyoming, used by Sposito, et al, (1983), has the unit cell formula,

$$M^{+}_{0.62}(Si_{7.80}Al_{0.20})[Al_{3.28}Fe^{3+}_{0.30}Fe^{2+}_{0.04}Mg_{0.38}]O_{20}(OH)_{4}$$

The subscript associated with each ion indicates the proportion of that particular element in the unit cell structure. The uneven number of ions out of which the basic montmorillonite unit is made up hints to the fact that this is a product of weathering and most likely not a final one. It is a mineral in the process of being weathered. Consequently, different chemical environments to which this mineral might be exposed will trigger different weathering pathways. Essentially, one of the main reasons for the reactivity of this clay mineral is the preponderance of defects in the internal structure (the group comprised in the square brackets) compared to those in the external structure (the silica and alumina comprised in the round brackets). In this particular case, 2/3 of the charge deficiency is located inside the structure in the so-called octahedral layer.

In their research with this particular clay, Sposito, et al, (1983) investigated the exchange of calcium and magnesium against the sodium of the original montmorillonite. They observed that

when the divalent cation was supplied as a chloride the (so-called constant) cation exchange capacity of the mineral, equal to 0.97 $mol_c\,kg^{-1}$ increased to 1.3 $mol_c\,kg^{-1}$ upon completion of the exchange reaction. The authors explained this by suggesting that divalent metals are being adsorbed in the presence of chlorine as complex ions, $CaCl^+$ or $MgCl^+$. This does not happen when the perchlorate is the associated anion. Such behavior hints to the versatility and oftentimes strange ways in which this clay mineral reacts in the environment.

Working also with a Wyoming bentonite, Smiles, et al, (1985) looked at the effect of sodium chloride salt concentration on the moisture characteristic relations. Such relations are presented in Figure 5.

Aware of the fact that we are dealing with a sodium system one should however wonder at the clear differences between the relationships corresponding to the three concentrations. Since the moisture characteristics are strongly related to all soil hydraulic properties including the conductivity, it is obvious that the rate of movement of solutions of different concentrations through (apparently) the same bentonite, will be different. Let us use this graph and explore some consequences.

SMILES ET AL (1985)

Figure 5

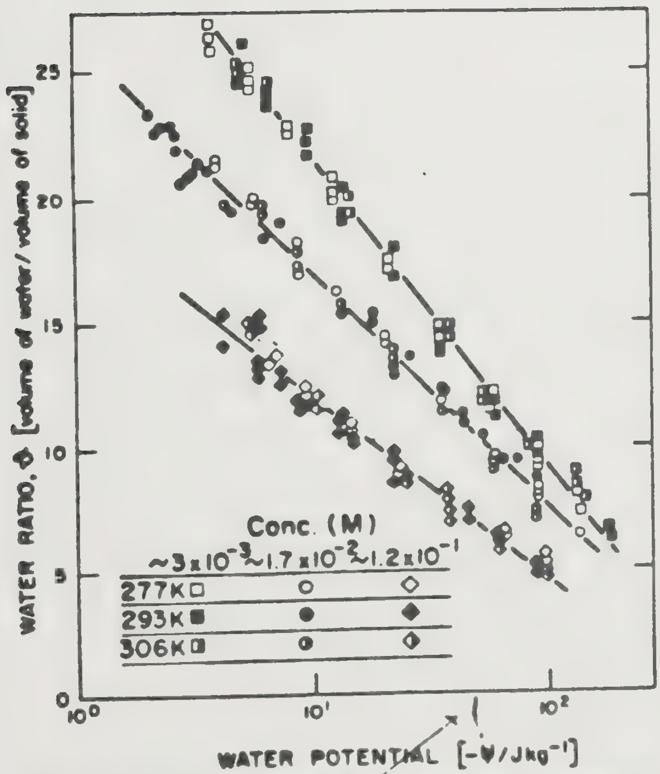


Fig. 1—Experimental data relating the water ratio, ϑ, (volume of water per unit volume of solid) to the water potential, Ψ, for samples of bentonite in equilibrium with three solution salt concentrations and three temperatures. The straight line regressions are consistent with diffuse double layer theory, but appear not to permit quantitative prediction. Temperature effects are not significant.

Let us assume that a sand-bentonite admix with a mass ratio of bentonite/sand equal to 0.052 is being prepared. Making reasonable assumptions on sand and bentonite specific densities, assuming a bulk density of the sand itself equal to 1.7 g/cm^3 and assuming that all water is associated with the bentonite, its volumetric moisture content is equal to 1000% when the system is saturated. If the concentration of the associated water is 3.10^{-3} $mole.L^{-1}$ the water potential of the system will be close to 1 bar according to Figure 5. Let us now assume that in time such a liner is permeated by a liquid of higher concentration, 0.12 $mol \cdot L^{-1}$. Although the original configuration of the bentonite in the sand matrix may not change there is the possibility that the replacement of the dilute solution by a more concentrated one will displace correspondingly the moisture characteristic curve. The pathway of the change in moisture characteristic from the point with coordinates Ψ = 0.9 bar and V = 10 located on the upper relation, toward the line corresponding to the highest concentration, cannot be a priori known. The infinite number of pathways seem to be bound however by two extreme pathways: one which is parallel to the water potential coordinate and a second one which is parallel to the water ratio coordinate. It is very consequential for the permeability of our hypothetical liner which one of the two is the pathway of moisture characteristic adjustment.

In a recent work, Frenkel, et al, (1983) have shown that the weatherability of a soil is a function of the composition of the

exchanger. At large ESP values the proportion of Ca and Mg released via dissolution increases substantially. Thus, altertion of chemical environments which modify the ionic composition of the exchanger are likely to have permanent repercussions on the clay integrity.

An interesting consequence of the close relationship between system chemistry and soil permeability was observed by Goldenberg and Magaritz (1983) at the sea water/fresh water moving boundary when investigating and analyzing a salt-water intrusion problem. In a simulated experiment, the Mediterranean sea water ($EC = 48.5$ m.mho·cm^{-1}) resulted in a K equal to $3.3.10^{-3}$ cm/s. Upon leaching the soil with fresh water ($EC = 0.78$ m.mho.cm^{-1}) the K dropped to $1.17.10^{-4}$ cm/s.

The information available at present on the subject of the effect of system chemistry on clay integrity indicates that in exceptional situations some clay liners can modify their as-prepared fabric and thus alter their flow transmission properties. Almost exclusively, instances when clay vulnerability were proven, they were associated with conditions in which the dominant clay mineral was a smectite, most often at a high exchangeable - sodium - percentage. Thus, one can conclude that in the alternative in which a clay-liner of a permeability not lower than 10^{-6}cm/s needs to be constructed, local soils of mixed mineralogy should be used if available.

Considering the solidgrounds of environmental control upon which we have recently embarked, it is hard to foresee that large clay volumes will ever be contacted by aggressive chemicals which will significantly alter them.

Subchapter 15 identifies the need to determine the soil/waste compatibility in Subsection 2541(b). In 2541(c) the method presented in Appendix I is suggested.

The procedure described in Appendix I can be made workable for some circumstances. For many others however the absolutely stated requirement that "Permeabilities specified for containment structures ... shall be relative to the fluids, including waste and leachate, to be contained" (2541b) will be hard, if not impossible, to follow. The methodology presented in Appendix I is not at all universal in the sense that not all possible leachates can be tested with the recommended procedure. Moreover, some of the calculations incorporated in Appendix I have a questionable theoretical background. Thus, the thought that the failure time of a clay liner in the field can be ascertained by performing a laboratory testing, is quite daring. At present there is a large body of information on "Scaling and General Similitude" which should be applied to this type of problems.

The determination of the permeability using a waste leachate, although very informative, requires usually very large times, when feasible. Alternatively, it would be very useful to develop

uncomplicated, expeditive and informative index compatibility parameters. In this respect one can follow for instance the example of Suarez, et al, (1984) who have measured by optical transmission the dispersion of three soils prepared at 5 electrolyte concentrations, 4 pH values, and 2 SAR (sodium adsorption ratios). This study was done to determine the effect of pH solution on the saturated permeability of investigated soils. Figure 6 presents the effect of concentration on the relative hydraulic conductivity on the left and percent transmission on the right. One can see the good correspondence between percent transmission as an indicator of dispersivity and hydraulic conductivity. This particular research identified the interacting effect of electrolyte concentration and solution pH and their combined effect on hydraulic conductivity. The exact effect could have been at least qualitatively predicted by the transmission data alone. The figure identifies the Arlington soil as the only one which does not disperse easily; it contains vermiculite, mica and kaolinite being the only soil which does not contain a substantial proportion of smectitic clay. A second set of data (not shown) was obtained for an SAR of $40(m.mho.L^{-1})^{1/2}$. They indicate the tendency of a soil to be dispersed at larger concentrations of sodium.

SUAREZ ET AL (1984)

Figure 6

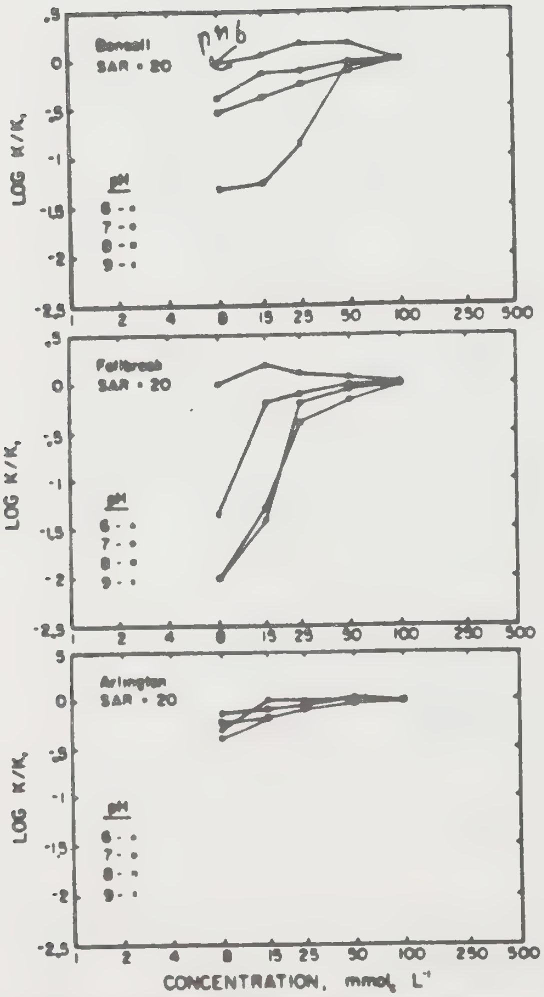


Fig. 1—Relative hydraulic conductivity vs. electrolyte concentration for Bonsall, Fallbrook, and Arlington soil at SAR = 20 and pH 6, 7, 8, or 9.

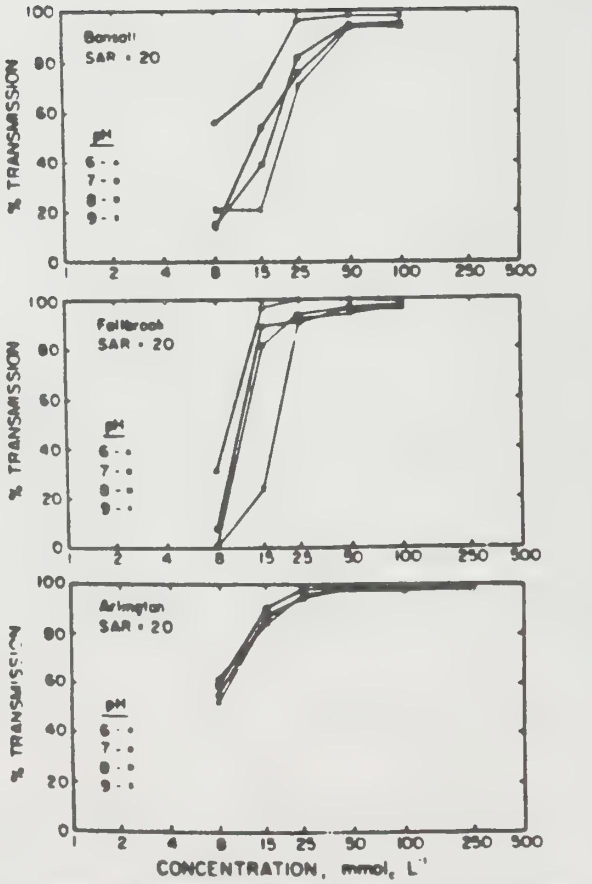


Fig. 3—Optical transmission (percent) vs. electrolyte concentration for Bonsall, Fallbrook, and Arlington soil at SAR = 20 and pH 6, 7, 8, or 9.

One can see that such compatibility procedures can be made available if we look for them.

The information provided in this section points to the fact that although chemically vulnerable clays in general should be considered immune to alteration when contacted by dilute waste leachates. Since dilute leachates represent the rule rather than the exception, one should expect clays to function efficiently as leachate barriers. The practice of waste disposal to land needs simple and informative testing procedures to assess the soils/ leachate compatibility.

Numerical flow modelling at disposal sites.

In an already classic work on the subject, Jacob Rubin (1983) has exposed the very different yet typical solute flow problems which are encountered and thus need to be addressed. By explaining his 6-key models he states their mathematical formulation and explains why a particular solute flow problem should be expressed mathematically in that particular way. Thus, a diversity of algebraic, partial - differential or integro - partial differential equations are matched with models in which local chemical equilibria is achieved fast or slow, the reactions occur in a single phase or cross phase boundaries, and whether they are surface or "classical chemistry" reactions.

From our perspective we should have a good understanding of our

waste chemistry, the characteristic leachate, and detailed information on soil significant material properties. We have then to predict the reaction mode between the chemical component(s) of our characteristic leachate and the soils. This will then allow us to choose a model which comes with its mathematical formulation.

With regard to such a simple (or simplistic) approach one question comes to mind: what if in time, due to the removal of some constituents from the waste, and because some of the soil material properties may be altered, what if due to all this the "characteristic" leachate changes its properties? For this second life episode of our hypothetical waste disposal site one can switch to another mathematical formulation. But do we know what the new waste, the new leachate and the new soil will look like? Above all, how can we simulate a process which is continuous in time by discreet episodes? This thought together with many others, casts doubts about using numerical modelling procedures in problems of contaminant migration through soils. No matter how approximate, they represent however our only hope to quantitatively analyze a particular situation. It is thus surprising that this powerful analytical tool did not find yet its place among the regularly accepted engineering procedures. It is about time that modelling - which is routinely done in the scientific community - becomes also a routine engineering practice.

The models described and mathematically presented by Rubin assume a lack of heterogeneity of the soil, and such was the trend until very recently. In 1972 in his comprehensive paper on flow in unsaturated soils, Klute states in his closing remarks that when predicting the flow in the field "...one faces the inescapable problem of soil variability, and there is need for <u>extensive</u> rather than <u>intensive</u> methods of characterization of the field soil. Meaningful average conductivity functions and probability statements as to the deviations from the average conductivity function are required". Similarly, Ragab, et al (1981) end their paper by stating: "The discrepancies between measured and predicted values (of unsaturated hydraulic conductivity)may be smaller than the differences often encountered in the field due to the natural spatial variability".

In the last approximately 10 to 15 years the need to account for the variability of soil properties when analyzing a flow problem, became obvious. Mualem (1984) simulating a sedimentary layered formation, calculated theoretically the consequences on the system as a whole of specific properties of different layers. His anisotropy analysis revealed that the ratio of the horizontal to the vertical unsaturated hydraulic conductivity can approach values of 100 in special situations.

The complex spatial variability of hydraulic properties was pointed out by Byers and Stephens (1983). The authors suggest that only describing such variability we can develop predictive

models of solute transport. Describing them means understanding their correlation structure in space. Thus, such stochastic analysis represent a more rigorous statistical approach, and according to many, the only rigorous approach. The authors determined the saturated hydraulic conductivity and some particle-size characteristics. The variability of permeability data along three transects is presented in Figure 7. One can see that along transect x they are two distinctly different K-value populations. The authors made a clear point in saying that visually this transect was perfectly uniform. Obviously, it was not.

On the subject of stochastic versus deterministic approaches of investigating soil hydraulic properties, one should mention the contribution made by the Volcani Center (Dagan and Bresler, 1983; Bresler and Dagan, 1983(a); Bresler and Dagan, 1983(b)). The investigation on the subject of salt movement through soils lead these authors to the conclusion that the statistical moment of salt concentration in a heterogeneous field can be determined by using simple flow models and thus further refinement of transport models does not seem to be justified. The authors recommend a better understanding of the variability structure of the field. It is also stated that stochastic modelling represents more realistically the actual solute transport phenomena. The authors state that for most conditions soil variability prevents the use of unsaturated - unsteady state hydraulic conductivity equation, simply because this equation assumes an "equivalent homogeneous

BYERS AND STEPHENS (1983)

Figure 7

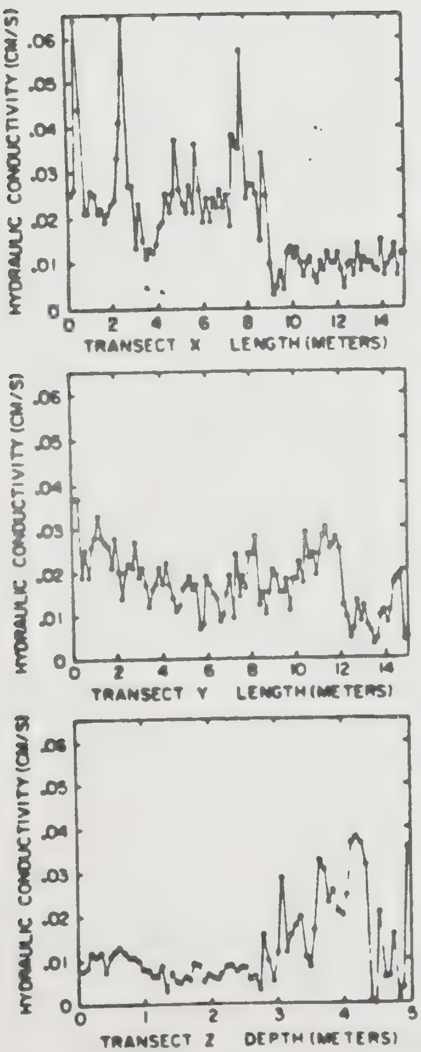


Fig. 2—Hydraulic conductivity vs. distance along transect.

soil", which most often does not exist in a natural environment. It is thus apparent that stochastic modelling research and its application as it relates to soil contamination should be encouraged.

In retrospect, this section dealt with the need to use quantitative analysis in routine engineering work when assessing contaminant migration through soils. Some ambiguities associated with numerical modelling were presented. In the future engineering practice the use of simple models based on stochastic rather than deterministic concepts should be encouraged.

CONCLUSIONS

1. In environments in which no excess of water is present on and around a site and where the groundwater is not superficial, the geologic suitability of an underlying soil should be judged by its unsaturated rather than its saturated flow characteristics.

2. Useful and semiquantitative computational procedures for calculating the permeability K as a function of volumetric moisture content Θ, are available. Most procedures use the K-saturated value and the moisture characteristic curve (Ψ/Θ function).

3. Some montmorillonitic clays can be altered by some strong

inorganic or neat organic solutions. Clays in general will not react with dilute solutions, certainly not to the extend of modifying their fluid transmission characteristics.

4. Along with determining the permeability of a particular soil with a leachate one should conceptualize simple, rapid and informative testing procedures to assess the clay/leachate compatibility. Such a procedure is presented in the text (optical transmission).

5. Although numerical modelling techniques have their own credibility problems they represent a good way to ascertain a contaminant flow pattern. Such procedures should find their way in routine engineering activities.

6. A relatively fresher approach to numerical modelling is the stochastic approach in which the statistical variability of soil hydraulic characteristics is accounted for. Relatively simple stochastic models seem to better reflect the field condition compared to the deterministic models which often are exceedingly complicated.

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CROSSLINKED PE TANKS FOR HAZARDOUS MATERIALS

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Introduction

For over a decade chemical tanks molded from Marlex® crosslinkable high density polyethylene, (XLHDPE) have been successfully utilized in a variety of hazard and corrosive chemical applications. In 1973 the first large capacity crosslinked polyethylene agriculture chemical tank (4000 gallon 15200 liter) was molded. The success of these tanks lead to the rapid development of larger tanks to be utilzed in more demanding corrosive chemical applications. Currently XLHDPE is expanding faster than any other material for storing and handling the hazard and corrosive chemicals. Crosslinkable high density polyethylene for rotational molding, Marlex CL-100, was commercialized by Phillips Chemical Company in 1970. The excellent chemical resistance and overall balance of physical properties of the material made it ideal for many industrial and agricultural chemical handling and storage applications. For several years rotational molded crosslinked tanks have successfully utilized the excellent chemical resistance in storage and process tanks for corrosive and hazardous chemicals. Other proven properties of chemical tanks molded from the Marlex crosslinkable resin are environmental stress cracking resistance (ESCR), long term hoop stress, outdoor weathering, impact strength and overall toughness. This resin gives industry an engineering type material capable of excellent service in many corrosive applications. In many applications the Marlex crosslinked tanks have replaced and out performed both fiberglass and stainless steel. Tanks varying in sizes from 5 to 15,000 gallons (19 to 56,780 liters) have years of experience in handling a wide range of concentration of acids, bases, salts and many organic compounds. Recently tanks up to 22,000 gallons (83,600 liters) capacity have been commercialized. Other recent developments are DOT approvals of XLPE tanks up to 630 gallon for transporting some hazardous chemical and exemption for shipping approved flammable material

For this paper all discussion and applications of crosslinked polyethylene is based on data and experience developed on Phillips Chemical Company's Marlex crosslinkable resin. Recently other crosslinkable resin have appeared but very little is known of the long term performance characteristics of these materials. From our experience with developmental crosslinkable resins, the crosslinked properties of the resin are controlled by the total system. Very small changes or variations in the additive system can have a dramatic effect on the performance of the molded part.

Physical Properties of Crosslinked Polyethylene

In general as the molecular weight of polyethylene increases, many properties which are required in the more demanding applications are improved. Basic properties such as long-term hoop stress, long term creep, outdoor weathering, environmental stress cracking resistance, impact and overall toughness are important for performance of polyethylene in highly stressed or constantly stressed applications. As the molecular weight of PE increases these properties are improved. Unfortunately, for polyethylene to be rotational molded it must have relativly low weights which means that the required basic proeprties for the more stressful applications will be reduced. Before the development of the rotational molding crosslinkable resins, rotational molded parts were limited to the less demanding and stressful applications.

The crosslinkable resin was a breakthrough for the rotational molding industry. It provided a low molecular weight resin which had good moldability and when crosslinked was converted into an extremely high molecular weight resin. Crosslinking greatly enhances the physical properties which are required for the more demanding industrial type applications. The overall property balance of crosslinked polyethylene will be superior to any commercially available rotational molding grade polyethylene and equal or superior to polyethylene used in any process.

To obtain the superior properties of the crosslinkable resin, proper processing conditions and quality control methods are required. Although in many applications marginally processed parts will give good service, for the parts to obtain optimum properties needed for long term performance in the more demanding applications good processing techniques are a must.

The nominal physical properties of Marlex CL-100 are given in Table I. Marlex CL-100 has outstanding environment stress cracking resistance (ESCR). This property gives an indication of how well polyethylene will resist failing when either in contact with a chemical which can cause some polyethylenes to chemically stress crack or when mechanical stresses are applied. In general, the lower molecular weight polyethylene, high melt index, will have lower ESCR values. Per ASTM D1693 test method, CL-100 has a F_{50} value greater than 1000 hours. Ten specimen samples are used to determine the F_{50} value. A properly crosslinked CL-100 sample will not have any failures of the ten specimens. A more severe test under ASTM 1693 uses 10% solution of the stress cracking agent, Marlex CL-100 will have similar values with this test as with the less severe 100% solution. Some of the recently developed non-crosslinkable rotational molding resins will have 1000 ESCR with the less severe test but with the 10% solution we have found none which will have 1000 hours and most have less than 150 hours. The improved ESCR of these resins is obtained basically by lowering the density of the resin. Although this does improve ESCR, other physical properties are adversely effected.

TABLE I

NOMINAL PHYSICAL PROPERTIES OF MARLEX CL-100

PROPERTY*	ASTM	ENGLISH Unit	ENGLISH Value	SI Unit	SI Value
Density**	D1505	g/cc	0.937-0.940	g/cc	0.937-0.940
ESCR, Condition A,F_{50}	D1693	h		h	
100% solution			1000		1000
10% solution			1000		1000
Tensile Strength, Ultimate 2"(50mm) per min.	D638 TypeIV	psi	2600	MPa	18
Elongation, At Break 2"(50mm) per min.	D638 TypeIV	%	450	%	450
Vicat Softening Temperature	D1525	^{o}F	260	^{o}C	127
Brittleness Temperature	D746	^{o}F	-180	^{o}C	-118
Flexural Modulus	D790	psi	100,000	MPa	689

* Physical properties are based on parts molded at optimum conditions.

** Density of the crosslinked product.

THE NOMINAL PROPERTIES REPORTED HEREIN ARE TYPICAL OF THE PRODUCT BUT DO NOT REFLECT NORMAL TESTING VARIANCE AND, THEREFORE, SHOULD NOT BE USED FOR SPECIFICATION PURPOSES.

For chemical tanks the long term hoop stress is one of the more important properties to be considered. The long term hoop stress is a major factor in determining the hoop stress to be used for designing tank wall thickness required for the various applications. For Marlex CL-100 long term hoop stress testing indicates that it is superior to non-crosslinkable rotational molding resins and equal or better than HDPE extrusion grade pipe resins. Marlex CL-100 rotational molded samples of 2" (50mm) diameter 0.150 (3.81mm) walls were used for hoop stress testing at both 80 and 140°F (23 and 60°C). One set of CL-100 samples at 1750 psi (12MPa) hoop stress and lower has gone greater than 80,000 hours without failure. It was anticipated that the samples with greater than 1700 psi (11.7MPa) hoop stress would fail in less than 1000 hours. Because sufficient failures did not occur, design hoop stress could not be determined; however, this test does indicate that a well crosslinked sample will have excellent long-term hoop stress at both 80 and 140°F (23 and 60°C). The data from these tests does indicate that this resin will have hoop stress similar to an extra high molecular weight pipe compound and superior to conventional HDPE pipe resins.

Another of the major properties to be considered for hazard chemical tanks is outdoor weathering, UV resistance. Regardless of the initial properties of a part, if the resin does not have good weathering characteristics, it will not give long-term performance outdoors. The CL-100 outdoor UV stabilized nature and color compounds have excellent weathering (UV) resistance. Although an estimated useful life is given in the Table II, the useful life of any product can be effected by the application requirements. The performance of a large stationary storage tank would be expected to be less effected by weathering than a small portable tank which is constantly being handled. Data developed in the Atlas Carbon Arc Weather-Ometer and outdoor exposure in Arizona indicated that CL-100 color compounds are far superior to other rotational molding resins and are better than most non-crosslinked HDPE resins. The Weather-Ometer hours and the outdoor exposure after six years in Arizona with estimated outdoor usefulness can be found in Table II. The weathered sample was considered to be useful until its elongation dropped below 10% and/or tensile dropped to 60% of its original value. Although 10% elongation and 60% of original tensile were used as a failure point for this study, it must be recognized that the relationship between these properties and product use would be dependent on each of the specific application. To estimate the outdoor life of a part, the requirements and type of service for each individual application have to be considered.

Other properties which are important in hazardous chemical handling and storage containers are impact and overall toughness. When properly processed Marlex CL-100 has exceptional impact strength over a wide range of temperatures. Good impact can be developed even for extremely low temperatures of -20 and -40°F (-29 and -40°C). As temperature increases the ductility of the material will increase improving its ability to withstand impact without cracking or shattering. The impact characteristics of Marlex CL-100 have been evaluated both by dart impact and part drop test. The dart test uses a section cut from a molded

TABLE II

WEATHERABILITY OF MARLEX CL-100 COLORS

COLOR	NUMBER	ARIZONA YEARS	WEATHER-OMETER HOURS	ESTIMATED USEFUL LIFE YEARS
Black	CL-100B	6+	23,000+	10
Terra Cotta	M2349G	6+	14,000+	6-10
Orange	M2348E	6+	14,000+	6-10
Red	M2350E	6+	14,000+	6-10
Gray	M5211A	6+	14,000+	6-10
Green	M4316B	6+	10,000	6
Dark Green	M4390D	6+	10,000	6
White	M6266A	6+	6,000	6
Natural	CL-100	2	2,000	1-2
Natural	CL-100JN	4+	8,000	4-6

\+ Indicates sample was still good after exposure period specified.

part and is impacted in a holder which has a 3 1/2" diameter unsupported area. The dart has a 1/2" radius point and weights either 10 or 20 pounds. Parts with heavy walls can withstand 200 foot-pounds of force at -20°F (-29°C) without failing. Two hundred foot-pounds of force is a 20 pound dart dropped from a height of 10 feet. Small tanks filled with water and anti-freeze have been dropped at room temperature and -20°F (-29°C) from 30' (9 meters) without failure. Another indication of toughness of the crosslinked part is the ability to withstand repeated drop impacts of 30' (9 meters) without failure. Even parts which have been creased on previous drops have withstood repeated 30' (9 meters) drops. Normally after creasing a non-crosslinked part will fail on the next drop. In service a tank which has good impact and toughness is less likely to be damaged from in service abuse and/or people and equipment working in the area.

In general, to predict part performance and service life by comparing data sheet type physical properties of plastics can be misleading. Comparing the data sheet properties of non-crosslinked to crosslinked polyethylene can be even more misleading. Many times the data sheet properties of the non- crosslinked polyethylene will have higher values than the crosslinked. With some properties higher numbers does not necessarily mean better part performance. Except for the environmental stress cracking resistance (ESCR), the data sheet properties of the crosslinkable resins give little indication of the excellent performance which molded parts have. Early in the development of crosslinkable HDPE, this was recognized and tests to give a better understanding of crosslinked parts performance were developed. These tests were designed to evalute such properties as ESCR, long term hoop stress, gasoline resistance, impact resistance and overall toughness. To illustrate the ability of a resin to perform under constant stress in a chemical environment at elevated temperatures, the hot room jerry can test was developed. The container molded for this test was a two gallon (7.6 liter) jerry can with flat ribbed side panels and a molded handle. The part had a wall thickness of 0.100" and weight 1.75 lbs (800g). The handle and ribs were areas where stress concentration might occur. For this test the two gallon jerry can was 75% filled with gasoline, sealed and placed in 130°F (50°C) hot room. At 130°F (50°C) the fuel had a vapor pressure of 7.5 psi (0.05 MPa). The crosslinked container was on test for three years and did not fail. Similar test run on the same container molded from non-crosslinkable resins available at that time had failures which varied from less than one hour to a maximum of four days. Recent tests on some currently available non-crosslinkable resins have taken 5 to 6 months to fail but still none have approached the durability of the Marlex crosslinkable resins.

Another test which was used to determine the ability of a crosslinked part to withstand repeated abuse was multi drop impacts of a molded part. A twenty gallon drum having a wall thickness of 0.100" was filled with water and repeatedly dropped from a height of 27 feet (8m). The crosslinked parts were dropped five times from 27 feet without failure. At the same time drums molded from recently developed linear low density

polyethylene rotational molding resins were tested. Some of these resins have dart impacts similar to the crosslinkable resins. A few of these drums did not fail on the first drop, but all of the non-crosslinked parts failed on the second drop. Inspection of both the crosslinked CL-100, and non-crosslinked parts revealed that all parts were creased on the first drop. On the second drop all the non-crosslinked parts failed in the area of the crease. Since the crosslinked part did not fail with four additional drops, the crease appeared to have very little effect on the crosslinked part. This illustrates another of the outstanding properties, good notch resistance, of the Marlex crosslinkable resins.

Chemical Resistance

For safe handling of hazard material and waste control the first major requirement is that the container have good chemical resistance. High density polyethylene is one of the most chemical resistant plastics available. This outstanding chemical resistance is basically due to the inherent stability of the very strong carbon-hydrogen bond with very little unsaturation in the molecule. It is virtually insoluble at room temperature. Crosslinked polyethylene is even insoluble at elevated temperatures and has chemical resistance equal or superior to uncrosslinked high density polyethylene.

When looking at chemical resistance, factors other than the results of testing by ASTM D543, Resistance of Plastics to Chemical Reagents, have to be considered. This test determines the effect the reagent will have on strength properties, appearance, dimensions and weight under no stress conditions. It does not determine the effect of the reagent when stresses are applied or define the permeation characteristics of the reagent. The chemical resistance for industry type applications require that all of the above along with the operating temperature be considered.

Chemical resistance charts for thermoplastics usually use ASTM D543 Procedure to determine resistance to chemical attack and ASTM D2684 to determine permeation characteristics. Although ASTM D543 may not indicate chemical attack for some reagents, if the reagent permeates the chemical resistance chart will rate the polymer as marginal or unsatisfactory for handling that reagent. Reagent permeation does have adverse effect on some of polyethylene properties. It causes a loss in tensile strength and flexural modulus. If a chemical does not attack or degrade the crosslinked part, proper part design can effectively offset the property loss due to permeation. Simply decreasing the tank hoop stress by increasing the wall thickness can offset the loss of these properties. The increased wall thickness will also reduce the rate of permeation. Several years experience has demonstrated that properly designed tanks can safely handle many chemicals which permeate.

Laboratory and field test data indicate that CL-100 is compatible with concentrated sulfuric acid. Non-crosslinked polyethylene is not recommended in this service. After two years of exposure to 80 and 98%

sulfuric acid at room temperature (RT), 120°F (44.5°) and 140°F (60°C), laboratory tests show very little change in tensile strength of the crosslinkable resins. This test data can be found in Table III. Another laboratory test was to fill a 0.125" (3.2 mm) wall 3 qt. (2.8 liter) rotational molded jar with 98% sulfuric acid and age at RT and 140°F (60°C). Periodically, tensile and elongation were determined on specimens cut from the side wall of the bottle (Table IV). In addition to laboratory tests, parts that have been in field service were tested. After four years service in 98% sulfuric acid, one 1500 gallon (5700 liter) tank molded from CL-100 and having a 0.4" (10.2 mm) wall was taken out of service and dissected. From several different locations in the tank, tensile bars were machined from the interior and exterior halves of the tank wall. There was no significant difference in the tensiles of the interior and exterior half of the wall. The results indicate that over this period of time the resin properties did not have significant deterioration (Table V). As shown in the attached tables both the laboratory and the field test indicate that the highly oxidizing concentrated sulfuric acid had very little effect on the performance of crosslinked polyethylene.

With both the laboratory test and the field sample, a brittle, 0.010" (.254mm) thick, black skin was formed on the inside of the part. The laboratory samples were tensile bars cut from rotational molded parts. When the tensile bars were submerged in 98% sulfuric acid, the black skin formed only on the inside surface. This skin forms very quickly when exposed to the acid. The skin is apparently the result of a reaction between the highly oxidized inner layer which is found in most rotational molded parts and the acid. The attack on the inner wall appears to be of minor consequence in a tank wall and is apparently terminated at approximately 0.010" (.254mm) depth.

On initial filling of a tank with concentrated sulfuric acid, a discoloration of the acid could occur. While suspected, it has not been reported, that this will occur with other highly oxidiziing chemicals. In most hazard chemical and waste control applications, this does not create a problem. If slight discoloration is objectionable, this should be related to the tank manufacturer. It is reported that some molders have developed techniques to eliminate this discoloration.

In determining the chemical resistance of CL-100 to dichromate cleaning solution (45 g/L sodium dichromate and 150 g/L concentrated sulfuric acid), black CL-100 jars were rotational molded and filled with dichromate cleaning solution. These jars were aged at 140°F (60°C) for eight months. Tensile strength and elongation of the jar walls were periodically determined. The cleaning solution, which is a strong oxidizing medium, did not significantly affect the resin properties. This data can be found in Table VI. After one month, discoloration of the liquid was observed.

TABLE III
Crosslinked HDPE/Sulfuric Acid Compatibility
MARLEX CL-100

Tensile Stength (psi) and Extension at Break (inch)

Time of Exposure, Months	CL-100, 98% Acid								CL-100, 80% Acid							
	0.5 in. (1.3 cm) thick				0.25 in. (0.6cm) thick				0.5 in. (1.3cm) thick				0.25 in. (0.6 cm) thick			
	psi	MPa	in	(cm)	psi	MPa	in	(cm)	psi	MPa	in	(cm)	psi	MPa	in	(cm)
Control	3400	23.4	1.5	(3.8)	3250	22.4	1	(2.5)	3400	23.4	1.5	(3.8)	3250	22.4	1	(2.5)
3	3350	23.1	1.4	(3.6)	3200	22.1	1.1	(2.8)	3300	22.8	1.5	(3.8)	3300	22.8	1.0	(2.5)
6	2500	24.1	1.2	(3.0)	3400	23.4	0.9	(2.3)	3400	23.4	1.3	(3.3)	3500	24.1	1.0	(2.5)
12	3400	23.4	1.2	(3.0)	3250	22.4	1.1	(2.8)	3400	23.4	1.5	(3.8)	3300	22.8	1.1	(2.8)
24	3400	23.4	1.2	(3.0)	3400	23.4	1.1	(2.8)	3400	23.4	1.4	(3.6)	3400	23.4	1.1	(2.8)
36	3250	22.4	1.2	(3.0)	3150	21.7	0.9	(2.3)	3200	22.1	1.5	(3.8)	–	–	–	–
48	3250	22.4	1.1	(2.8)	3200	22.1	1.0	(2.5)	3300	22.8	1.3	(3.3)	3150	21.7	1.0	(2.5)
1	2750	19.0	1.0	(2.5)	3200	22.1	1.0	(2.5)	4100	28.3	1.5	(3.8)	3300	22.8	1.0	(2.5)
2	3200	22.1	1.0	(2.5)	3200	22.1	1.0	(2.5)	3900	26.9	1.5	(3.8)	3300	22.8	1.0	(2.5)
4	3200	22.1	0.5	(1.2)	3150	21.7	0.4	(1.0)	4150	28.6	0.7	(1.8)	3200	22.1	0.5	(1.2)
8	3200	22.1	1.6	(4.1)	3050	21.0	1.1	(2.8)	3250	22.4	1.9	(4.8)	3450	23.8	1.3	(4.3)
16	3400	23.4	1.3	(3.3)	3300	22.8	1.0	(2.5)	3150	21.7	1.6	(4.1)	3350	23.1	1.1	(2.8)
24	3400	23.4	1.2	(3.0)	3400	23.4	0.9	(2.3)	3400	23.4	1.8	(4.6)	3400	23.4	1.0	(2.5)
36	3150	21.7	1.0	(2.5)	3100	21.4	0.7	(1.8)	3200	22.1	1.5	(3.8)	3200	22.1	1.0	(2.5)
48	3200	22.1	1.1	(2.8)	3000	20.7	0.8	(2.0)	3350	23.1	1.2	(3.0)	3400	23.4	1.0	(2.5)
4 days	4000	27.6	1.2	(3.0)	3200	22.1	1.0	(2.5)	4000	27.6	1.5	(3.8)	3500	24.1	1.2	(3.0)
8 days	3950	27.2	1.0	(2.5)	3300	22.8	1.0	(2.5)	3700	25.5	1.2	(3.0)	3300	22.8	1.0	(2.5)
16 days	3800	26.2	1.1	(2.8)	3100	21.4	1.0	(2.5)	4050	27.9	1.2	(3.0)	3200	22.1	1.2	(3.0)
32 days	4000	27.6	1.2	(3.0)	3100	21.4	1.0	(2.5)	4000	27.6	1.2	(3.0)	3150	21.7	1.0	(2.5)
64 days	3550	24.5	1.0	(2.5)	3100	21.4	1.0	(2.5)	4100	28.3	1.2	(3.0)	3250	22.4	1.0	(2.5)
14 mos.	3250	22.4	1.7	(4.3)	3100	21.4	0.9	(2.3)	3250	22.4	1.5	(3.8)	3300	22.8	1.2	(3.0)
24 mos.	–	–	–		3400	23.4	0.9	(2.3)	–	–	–	–	3200	22.1	1.4	(3.6)
36 mos.	3300	22.8	1.5	(3.8)	3150	21.7	0.8	(2.0)	3300	22.8	1.5	(3.8)	3200	22.1	0.9	(2.3)
48 mos.	3250	22.4	1.2	(3.0)	3250	22.4	0.8	(2.0)	–	–	–	–	–	–	–	–

TABLE IV

MARLEX CL-100/SULFURIC ACID COMPATIBILITY

Tensile Strength and Elongation - Specimen Cut from Wall of 3qt. (2.84 L) CL-100 Bottle

Time of Exposure, Months	Room Temperature						140°F (60°C)					
	Control			H_2SO_4 Filled						H_2SO_4 Filled		
	Elongation, percent	Tensile psi	Tensile MPa	Elongation, percent	Tensile psi	Tensile MPa	Elongation, percent	Tensile psi	Tensile MPa	Elongation percent	Tensile psi	Tensile MPa
3	250	2750	19.0	330	2600	17.9	100	2800	19.3	40	2700	18.6
6	200	2550	17.6	210	2600	17.9	90	2700	18.6	40	2300	15.9
9	190	1850	19.7	40	2800	19.3	80	2900	20.0	40	2850	19.7
12	160	2850	19.7	40	2900	20.0	70	3000	20.7	20	2750	19.0
15	200	2800	19.3	30	3000							
18	150	2750	19.0	10	2700							
21	200	2850	19.7	30	2950							

140°F (60°C) Testing Terminated After 12 Months

TABLE V

Marlex Crosslinked/Sulfuric Acid Compatibility

GEL AND TENSILE RESULTS - STORAGE TANK

(4 years service in 98% H_2SO_4)

	Sample Location on Tank											
	Bottom		Bottom Corner		Side Near Bottom		Side Near Top		Lid		Sump	
Gel, wt. %	79.8		76.0		83.4		53.1		49.1		92.0	
	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	Mpa
Tensile Strength,												
2" (50.8 mm) per minute												
Interior Half	3050	21.0	3050	21.0	3200	22.1	2300	22.1	3150	21.7	3200	22.1
Exterior Half	3200	22.1	3300	22.8	3200	22.1	3200	22.1	3150	21.7	3100	21.4
20" (508 mm) per minute												
Interior Half	3900	26.9	3800	26.2	3800	26.0	3900	26.9	3800	26.0	3850	26.6
Exterior Half	3700	25.5	3650	25.2	3600	24.8	3600	24.8	3600	24.8	3500	24.1
Elongation, %												
2" (50.8 mm) per minute												
Interior Half	30		20		30		30		30		30	
Exterior Half	50		30		30		30		30		40	
Full Wall	50				50							
20" (508 mm) per minute												
Full Wall Thickness	40		40						40			

TABLE VI

BLACK ROTOMOLDED JARS FILLED WITH DICHROMATE/ACID

Time of Exposure, Months	Tensile		Elongation, percent	Tensile		Elongation, percent
	psi	MPa		psi	MPa	
Unaged	2650	18.3	100-150	-	-	-
1	2600	17.9	50-200	2650	18.3	50-350
3	2550	17.6	100-550	-	-	-
8	2600	17.9	50-350	2600	17.8	100-500
8 (empty jar)	-	-	-	2500	17.4	150-500

Applications

Over the last decade and a half, a wide variety of products utilizing the overall excellent balance of physical properties of Marlex crosslinkable resins have been developed. Some of the initial products developed were a one quart small engine and 4 and 5 gallon snowmobile fuel tanks, small (50 to 100 gallons - 190 to 380 l), agriculture chemical tanks, trash containers for automated collection systems and industrial battery jars. All of these products utilized Marlex crosslinkable polyethylene because non-crosslinked polyethylene and other plastics had given poor or unsatisfactory service in these applications.

The success of the small agriculture chemical led to the development in 1973 of the first large agriculture chemical tank. Following the success of this 4000 gallon (15200 liters) tank and the second large tank 5600 gallon (21280 liters) tank, development of larger volume tanks quickly followed. Currently tank varying in size from 5 to 22,000 gallon (19 to 83600 liters) are being used for handling and storing a wide variety of agriculture and industrial chemicals including many hazardous material. These chemicals include such products as fertilizer, herbicides, insecticides, acids, bases and hazardous waste materials including low level nuclear waste. Crosslinked tanks have had years of experience in handling many concentrations and conbinations of these products.

One of the fastest growing applications for the Marlex crosslinked tank is for industrial and hazardous material storage. This type of application was dormant until the development of the larger tanks and their successsful service with agriculture chemicals. Once proven for handling agriculture chemicals the crosslinked tank expanded rapidly into the industrial large tank market. Commericalization in 1980 of the 13,000 and 15,000 gallon (49,400 and 57,000 liter) tanks created additional applications for handling and storing hazardous materials and industrial chemicals. To date only a small percentage of the potential applications for crosslinked tanks in the chemicals and hazardous waste industry has been developed. As the long term performance and economics of the crosslinked polyethylene tanks are further proven and become better known, mass expansion into the many potential applications in the hazardous waste and chemical industry is expected. The ability of some rotational molders to customize products for individual applications will be another factor in the expansion of new applications.

In many areas where fiberglass tanks failed or were giving only marginal service, the crosslinked tanks have succesfully replaced them and are giving excellent service. Crosslinked tanks have given good performance for several years with chemicals such as sodium hypochlorite, sodium hydroxide, hydrochloric acid, sulfuric acid, and detergents. Marlex crosslinked tanks are being used in the manufacture and storage of bleach and other chemicals. Food processing plants, electronics plants, sewage treatment plants, paint manufacturers, oil well service companies, galvanizing companies, sugar refineries, aircraft

companies and floor cleaner and finish manufacturers are some of the many areas in which crosslinked tanks are used. For food processing that requires FDA or USDA approvals, specially designed tanks have to be used.

One interesting hazardous material application is the use of crosslinked tanks in the neutralization of waste chemicals before being disposed. The crosslinked tanks replaced both stainless and carbon steel tanks. The first tank to be used in this type application was a 6000 gallons (22,800 liter) tanks. In five years of service the tanks have far exceeded expectations and in most cases have given better service than either the steel or stainless steel. It was reported that a strong base was accidentally dumped into one of the 6000 gallon tanks containing about 1000 gallons (3800 liters) of concentrated acid. Considerable heat and some pressure were generated. The diameter for the bottom third of the tank increased about three feet, but the tank did not fail. It was speculated that under these conditions a steel tank would have ruptured. After six months the bottom diameter returned to near its original size and three years after this incident the tank is reported to be still in service.

A somewhat similar application is the use of large open-head tanks for sludge pits or settling ponds. These tanks are generally black and could have a spray system installed to increase the rate of evaportation. With current governmental regulations on sludge pits, the open-head tank could be more economical than a sludge pit. The system has been approved by the California environmental regulatory agents. Another application for the open-head tank is an overflow containment vessel replacing the diked pit. In this applications an open head container is placed on a flat concrete pad and a vertical storage tank is installed inside the open head container. With this type installation an underground monitoring system is not required.

Two electronics companies are using crosslinked tanks in their plating systems. One company is using 6500 gallon tanks as waste plating solution tanks. Both acidic and basic solution go into these tanks. Orginally the specifications were for FRP tanks but after visits to local crosslinked tank users and investigation of the tank's chemical resistance, the engineers were convinced crosslinked tanks offered many advantages over FRP. To meet the requirements of a sloped bottom tank with a sump, the tank pad was convex and sloped. A downpipe from the tank's domed top to the low point achieves near complete drainage. Another electronics company is using crosslinked tank as HCL and H_2SO_4 storage tanks. Also prior to treatment this company stores their hazard wastes in crosslinked tanks and utilizes crosslinked tanks in their treatment system. Most of these tanks are in a large concrete pit which has a chemical resistant liner.

An aircraft company is utilizing a 6500 gallon (24,700 liter) underground tank as a hazardous waste washdown holding tank. The tank is installed in a poured-in-place concrete vault. To meet EPA requirements a leak monitor is placed in the vault sump. The waste hauler has access to the tank through a manway in the vault.

Tank rental companies are utilizing crosslinked tanks as temporary holding tanks for hazardous waste clean up operations. The crosslinked tank's wide range of chemical resistance and its toughness make it ideal for this type of operation. The rental company can respond in a matter of hours by transporting the tank on a hydraulic tilt trailer. The tanks are equipped with PVC valves on molded flanges, a vent and a ladder. The crosslinked tanks make possible this valuable serivce to hazardous waste clean up companies and hazardous waste producers.

Another crosslinked product which will find many areas of applications in hazardous waste handling and clean up is the recently introduced Enviropack® salvage drum. The Enviropack is an 85 gallon (323 liter) container used for storage of chemical waste or as an overpack for corroded or leaking 55 gallon chemical drums. The 85 gallon (323 liter) container has received D.O.T. exemptions for transporting hazardous materials. It is reported that after tranporting leaking drums, an Enviropack unit can be cleaned and reused which makes it more economical than conventional steel overpact units. As an example, a company could transport a corroded acid filled drum, neuturilize the acid that leaked into the Enviropack drum and on the return trip ship a drum of caustic soda in the same overpack. It is planned to develop additional Enviropack units. A nestable 90 gallon (342 liters) unit for handling 55 gallon drum, when not in use, the nestable unit can be stacked and save storage space. Other planned expasion will include a 1 to 2 gallons (3.8 to 7.6 liter) Envirolabpack container, and overpack units to handle 5 to 30 gallon (19 to 114 liters) containers.

A fairly new product is the cone bottom tank. This was designed for handling liquids which require periodic agitation to keep solids suspended or for corrosives powder or granules. The cones have two designed slopes, 45^{o} and 60^{o}. Normally, the 60^{o} cone is used with powders and granules. An advantage other than chemical resistance of the polyethylene cone bottom tanks is that the powder has less tendency to stick to polyethylene than metal. If sticking does occur, the flexibility of the polyethylene makes it easier to vibrate the powder free. These tanks are available in several capacities ranging from 700-6500 gallon (2660-24700 liter).

A system for bulk handling of corrosive and hazardous chemicals utilizing crosslinked tank has been developed. Designed to be reuseable, the bulk handling tanks will eliminate the need to dispose of bottles, cans or drums containing hazardous chemical residue. Tanks having capacities from 100 to 630 gallons (380 to 2394 liters) are currently being used. All of the designs can be handled with forklifts and some are stackable. To be transported these containers were required to meet D.O.T. standards. In addition to having D.O.T. exemptions for handling hazardous materials, some of the designs have approval for handling certain flammable material with flash points as low as $73^{o}F$.

Fuel tanks molded in CL-100 resin have had outstanding successes. One of the first large capacity fuel tank applications for crosslinkable resins was the J. I. Case farm tractor. This tank has a capacity of 80 gallons (300 liters). The success of this tank paved the way for other tractor fuel tanks. J. I. Case added a 50 gallon (190 liter) tank to their line. This was followed by International Harvester and Massey Ferguson utilizing two similar tanks in one line of their tractors. All of these tanks are in service in both diesel and gasoline tractors. In addtion to tractors, crosslinked fuel tanks are being used on MI Army battletanks, snowmobiles, small lawn tractors, motorcycles, boats, and small engines applications. Powder boat fuel tanks use is expanding rapidly and development of fuel tanks as large as 250 gallons (950 liters) is projected.

Typical products which have been successfully handled in tanks molded from Marlex crosslinkable resin can be found in Table VII. These products have a wide range of concentration of both organic and inorganic chemicals. Many of these products were first commercially handled in smaller tanks. As the performance of smaller tanks was proven, the size of the tanks increased until today 12,000 gallon (45,360 liter) and larger tanks are being used for these and other corrosive and hazardous chemicals. As indicated by years in service given in Table VII, the Marlex crosslinkable resin has years of proven service in many chemicals for both small and large tanks.

In addition to the proven chemical resistance, the tanks are proven to be resistance to seismic disturbance. For seismic unstable areas some molders have a seimic restraint systems designed to be used with the crosslinked tanks.

Conclusion

Field experience has demonstrated the ability of Marlex CL-100 to give outstanding service in a variety of corrosive environments. As indicated by field experience and laboratory test, other than very strong oxidizing agents, crosslinked polyethylene will not be attacked by organic or inorganic compounds. Although some solvents will permeate crosslinked polyethylene, most solvents will not chemically attack it. The effect of solvent permeation can easily be offset by proper part design. In many industrial, agricultural and hazardous waste applications crosslinked parts have given years of outstanding performance. Because of this experience and current development projects, a substantial increase of crosslinked applications in these areas is projected.

The overall toughness and balance of Marlex crosslinked polyethylene combined with its excellent chemical resistance gives industry an engineering type material to be used in corrosive environments. Tanks or other parts can be designed which will give long term, consistent and predictable performance in highly stressed and harsh corrosive environments. In many of the more demanding environments where non-crosslinked rotatonal molded polyethylene and other materials have failed, Marlex crosslinkable polyethylene has performed well.

TABLE VII

APPLICATIONS OF CROSSLINKED HDPE CHEMICAL TANKS

Chemical Handled	Size of Tank (gallons)	Years in Service
Alum	5600	8
Ammonium Fluoride & HF (Exotherm to 140°F 8 hr/day)	1050	3
Aqua Ammonia	6-13,000	5-8
Asphalt Slurry Emulsion	13,000	5
Cactus Juice	1500 to 6000	7
Cattle Supplements	5600	9
Detergents	100 to 6000	9
Dichloropropane	6000	5
Floor finishes & Cleaners	5600	8
Herbicides (Bicep, Dual, Sutan, Lasso)	50 to 1500	12
Hydrochloric Acid (37% and lower)	5600	8
Hydrofluoric Acid	55 to 1500	6
Hydrofluosilicic Acid	3100	1
Hydrogen Peroxide (52%)	55	5
Insecticides	50 to 1500	12
Latex	2500	7
Liquid Fertilizer	100 to 5600	10
Muriatic Acid	55	6
Nitrogen Solution	5600	10
Oil Well Additives	200 to 1500	10
Phosphoric Acid	1500 to 5600	10
Plating Solutions	3000	6
Propionic Acid	5600	10
Sodium Hypochlorite	4250 to 12,000	7
Sodium Hydroxide	1500 to 12,000	8
Sulfuric Acid (98% and lower)	400 to 12,000	10
Toluene Sulfonic Acid	5000	2
Treflan	200	8
Waste Water	1500	7

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EVALUATION OF CHEMICAL FATE AND MOBILITY

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Introduction

The complete characterization of a site with contaminated soil or groundwater often requires a variety of scientific and engineering expertise. The subsequent evaluation of possible measures to remediate the contamination also requires different types of information and expertise to guide decisions on what clean-up actions are the most cost-effective for minimizing human and environmental exposure to the chemical contaminants present at the site. This paper discusses some of the principles and considerations in evaluating the mobility and fate (the ultimate disposition) of chemicals as part of these site assessment and remedial action processes.

As a background to discussions on chemical fate and mobility at a site, it is important to recognize that soil is a heterogeneous porous material, with soil particulate matter occupying 60%-90% of a volume of soil. The remaining volume of soil is occupied by "soil air" and/or "soil water." Soil above the water table (in the unsaturated or vadose zone) may contain differing amounts of soil air and soil water depending on water sources that provide infiltrating water (rainfall, irrigation, or surface discharges). Below the water table, the soil is saturated with water (no soil air pores exist); this saturated soil zone is the region that is the source of groundwater. The discussion below deals solely with how chemicals behave in the soil/soil-water system; except for unique situations, chemical movement/chemical reactions in the soil air are less important as a major exposure pathway for chemical movement or transformation compared with water-borne routes.

Mobility of Chemicals in Soil/Water Systems

The rate of movement of a chemical through a soil/water system is dependent on both the properties of the chemical and of the system itself. Because the soil/water environmental system has a heterogeneous character that varies with location and time, the properties of the system are usefully regarded as environmental variables. By contrast, many properties of a chemical are intrinsic to the structure of the chemical, and practically invariant under most environmental conditions. The

ability to distinguish between and study the importance of individual environmental variables and chemical properties has significantly advanced the understanding of environmental chemistry, and obviously provides a powerful approach for predicting how a chemical will behave in any soil/water environment.

A key concept in evaluating the mobility of a chemical in a soil/water system is the partitioning of the chemical between soil particulates (hereafter called soil) and soil water (called water). If a nonpolar organic chemical is present at low concentrations in water and soil, the chemical concentrations in soil and in water at equilibrium (C_s and C_w, respectively) are often related by the simple expression

$$K_d = \frac{C_s}{C_w}$$

where K_d is called the soil/water partition coefficient of the chemical (1, 2). This expression is very useful because it has been shown that in most soil/water systems, K_d is related to the fraction of organic carbon in soil, f_{oc}, and a property of a chemical, K_{oc} (K_{oc} is referred to as an organic carbon-normalized soil partition coefficient).

$$K_{oc}\ f_{oc} = K_d = \frac{C_s}{C_w}$$

Thus a knowledge of f_{oc} for a soil and the K_{oc} value for a chemical allows for calculation of C_s/C_w; information on C_w also allows for calculation of C_s.

As an example of how partitioning affects the chemical concentration in water and soil, let us assume that two chemicals, A and B, are each found in groundwater at concentrations of 10 mg/L (or 10 ppm). If A has a value of $K_d = 1$ and B has $K_d = 10^3$, use of the equation shows that the soil that was in contact with the water has a concentration of A and B at levels of 10 ppm and 10^4 ppm, respectively. These data clearly show that soil can have a marked effect in affecting the concentrations of some chemicals in soil/water systems.

To further demonstrate the effect of partitioning in affecting concentrations of chemical in groundwater, let us further assume that the water containing the 10 ppm concentration is instantaneously mixed with a 750 gm clean soil sample where the water to soil weight-ratio is 250:750 (1 Kg total soil and water). The concentrations of A ($K_d = 1$) in soil and water (C_s and C_w, respectively) are then calculated both to be 2.5 ppm. However, for chemical B (where $K_d = 10^3$), the new concentration in soil is 3.3 ppm, whereas the concentration in water is 0.0032 ppm!

This calculation shows that movement of contaminated groundwater into clean soil can reduce the chemical concentrations in water, and that the decrease in concentration is ultimately a function of an environment variable (f_{oc}) and of a chemical property (K_{oc}). It also

follows that clean water flowing into contaminated soil will necessarily become contaminated with chemicals, but that the chemical concentrations will again decrease when the water moves into clean soil. A comparison of the effects of partitioning on the individual concentrations of A and B in water also shows that A will be more "mobile" than B in a continuous flow system (like groundwater) because a larger fraction of A remains in the mobile water phase; put another way, the dominant partitioning of chemical B to the non-mobile solid phase will retard the chemical's movement in the mobile aqueous phase (i.e., partitioning limits the amount of chemical that is available to move with groundwater).

The mathematical expression for predicting the velocity of chemical movement, V_c, in groundwater with a flow velocity, V_w, is given by the expression

$$V_c = V_w \left(1 + \frac{\rho_b}{n} K_d\right)^{-1}$$

or

$$V_c = V_w \left(1 + \frac{\rho_b}{n} K_{oc}\, f_{oc}\right)^{-1}$$

where n is the soil porosity, and ρ_b is the bulk mass density of the soil/water system; an excellent description of the meaning and use of this equation can be found in Freeze and Cherry (3). Importantly, this equation shows that the velocity of a chemical's movement through a groundwater system is a function of both environmental variables (V_w, ρ_b, n, f_{oc}) and of a chemical property (K_{oc}), and that the mobilities of chemicals at a given contaminated site can be evaluated from their K_{oc} values. It must also be recognized that these equations apply strictly to organic chemicals, but that K_d values for an inorganic chemical could also be used if only the transport of that chemical is of interest (see below).

The mobility of inorganics species (including metals) in soils and groundwaters is, however, more difficult to predict (or even to understand in some situations) because some elements can be present in one or several oxidation states, and each state exhibits its own chemistry in interacting with soil particulates, soil organics, and other inorganic constituents (4); the formation of these different forms is referred speciation. Depending on the speciation of the inorganic components, the element of concern may be found to have various degrees of mobility in a particular environment (5). Some of the environmental variables that affect the mobility of metals are discussed below.

A general rule for assessing the mobility of some heavy metals (for example, Pb, Cd, Zn) in soils is that they are immobile above pH 6.5. This behavior is largely due to the binding of metals to soils by cationic exchange and other mechanisms, and by precipitation of metals in the carbonate, oxide and hydroxide forms; as discussed above, the immobility designation actually is a result of the major concentration of chemicals being present in a non-mobile state, and that very low

concentrations of metals do exist in the mobile phase as different species.

Ionic organic materials present in soil or groundwater also can affect the mobility of metals because they compete with soil or other soil constituents to complex the metal. If the organic-metal complex itself partitions strongly to soil solids, another route for metal immobilization obviously exists. However, if the organic-metal complex is partitioned predominately to the aqueous phase, the metal is "mobilized." From this brief discussion, the processes that govern the mobility of metals are obviously very complicated; an example of this speciation of metals is discussed further in another section.

The above discussion has focused primarily on groundwater environments where water flow through soil solids is continuous. However, the same principles of partitioning and mobility apply to the unsaturated zone, where a major problem in estimating chemical mobility is evaluating the discontinuous water flow through the soil profile. It is also important to recognize that solvent plumes or high concentrations of organics will cause the simple partitioning expression to fail (soil sites will be saturated with organics and chemical will partition in very different ways), and that the mobility can only be evaluated from site specific analytical data.

Fate of Chemicals in Soil/Water Systems

A number of different reaction processes may occur in unsaturated soil or groundwater systems that transform chemicals into new chemicals (or products). The rate of each process that transforms a chemical (or generates a product) depends both on the inherent reactivity of a chemical toward the process (i.e., hydrolysis, oxidation, etc.) and the environmental variables that affect or influence the transformation reaction (variables may include pH, water, oxygen, type and population of microorganisms, and major and minor nutrients). For some chemicals in some environments, several processes may compete to transform a chemical.

Unfortunately, the heterogeneous character of the soil/water system and the complex interrelationships between the environmental variables themselves prevent an accurate prediction of what processes or reaction rates will occur for a chemical at a given site. However, the geochemical and microbial factors that control the production and levels of some important environmental variables have been studied in laboratory and field experiments. This information, together with a knowledge of the reactivity of chemicals, can be used to explain why some transformations have occurred, or to qualitatively predict what reactions will (or will not) occur at a given site (6).

As an example of the complexity of the transformation processes that can occur at a site, let us assume that a plume of gasoline from a leaking tank commingles with a TCE plume in a normally oxic (oxygen containing) saturated zone, and that some heavy metal wastes are also present in the saturated zone soils; TCE is generally resistant to chemical

or biological transformations in oxic systems, and heavy metals are not mobile in soils above pH 6.5, as discussed above.

The presence of the gasoline hydrocarbons will change the oxic nature of the soil/water system as the microbial populations in the system oxidize the hydrocarbons to organic acids and eventually CO_2.

$$\text{hydrocarbons} + O_2 \longrightarrow \text{organic acids}, CO_2$$

Consumption of oxygen in the subsurface soil system can result in anoxic (or anaerobic) conditions. It is now well established that halohydrocarbons can be chemically or microbially transformed in anoxic environments, with reduction of TCE to give vinyl chloride having received considerable study (7,8); thus it is entirely reasonable to expect vinyl chloride could be present in the commingled plume.

$$\text{TCE} \xrightarrow[\text{conditions}]{\text{anoxic}} \text{vinyl chloride}$$

The generation of anoxic conditions and organic acids by the biotransformation of hydrocarbons will also result in heavy metals (M) being mobilized in groundwater by several mechanisms. One mechanism is the acidification of soils to below pH 6.5 by the acid biotransformation products; the production of low molecular weight organic acids also can shift the metal equilibria in soil/water systems to produce higher concentrations of the more mobile organic acid-metal complexes. Heavy metals will also be released for possible mobilization because insoluble ferric oxide/hydroxide species in soil will be reduced to soluble ferrous species, and the binding of heavy metals to the ferric oxide constituents is one important mechanism for immobilization of metals.

$$\underset{\text{IMMOBILE}}{(\text{soil/organic—M})} + (\text{low molecular weight acids}) \longrightarrow \underset{\text{MOBILE}}{(\text{M—low molecular weight acid complexes})}$$

$$\underset{\text{MOBILE}}{(Fe^{+3}\ \text{oxy/hydroxide—M complexes})} \xrightarrow[\text{conditions}]{\text{reducing}} \underset{\text{MOBILE}}{(\text{soluble } Fe^{+2})} + (\text{M})(\text{POTENTIALLY MOBILE})$$

The multiple interrelationships for constituents (natural and anthropogenic) in soil/water systems and their implications for the transport and transformation of chemicals in the system clearly show that the possible fates of each chemical must be considered in the site assessment process. As demonstrated in the example above, this information is vital for developing a cost-effective and safe remedial action plan (i.e., the presence of vinyl chloride presents a health hazard, and both metals and volatile organics may have to be removed from groundwater).

The Site Assessment

Because of the important information it provides for evaluating clean-up alternatives and exposure, a site investigation must be carefully designed to determine the degree of heterogeneity that exists in the environmental variables and in the chemical constituents and their concentrations at a site. When the site contamination results from one spill event or one type of discharge, and the range of each important environmental variable is small, the evaluation of the fate and mobility of chemicals at the site often can be reasonably straightforward. At large sites where chemicals with different mobilities or reactivities are present, the assessment may require more extensive analysis, possibly defining the fate and mobility of chemicals in subenvironments where certain chemicals exist or where the soil or groundwater region is reasonably homogeneous in character. Chemical waste "dumps" are often a particular challenge for a site assessment because the concentrations and variety of chemicals present can create a "new environment" that is unlike any other system in how it affects the fate and mobility of each constituent. Whatever the type and extent of soil or groundwater contamination, it is important to always remember that the primary purpose of a site assessment usually is to obtain information for evaluation of remedial alternatives for the site. At many sites, a concept of the important sources and the fate and mobility of chemicals can be used to design a monitoring plan that provides the necessary site information and minimizes the costs of extensive soil and groundwater monitoring.

A phased site assessment is often useful where significant geologic/hydrologic or chemical heterogeneity is thought to exist at a site. Thus a preliminary investigation is performed to determine the extent and type of chemical contamination and to measure certain environmental variables (pH, TOC, hydrogeologic parameters). This information, along with reasonable estimates on the fate and mobility of the chemicals at the site, then allows the site to be more selectively characterized in a second phase of the assessment. This second phase may also include analyses for specific products of transformation reactions (such as vinyl chloride). If issues such as multiple possible sources exist at a site, analyses for a specific chemical tracer can be conducted and used with fate and mobility arguments for estimating the contribution from each source. Importantly, if the results of the second phase study are in accord with the expected fate and mobility of chemicals at a site, the confidence in the understanding of the site is often sufficient for actions that focus on remedial actions for the site.

Remedial Actions

A number of alternative remedial measures are often available for reducing or eliminating the exposure of contaminated soils or groundwaters to humans or other environmental species. Some of the remedial measures involve taking advantage of the mobile (or immobile) behavior or reactivity of a chemical, possibly managing the soil or groundwater system to enhance a desired behavior. Because of the necessity of assuring that a particular remedial action will indeed meet the clean-up

requirements of the property owner and regulatory agencies both in the short term and long term future of the site, additional studies are usually required to obtain information not usually obtained during a site assessment.

Acquisition of this information can require laboratory studies using site soils and water samples to most closely simulate site conditions. Additional geological/hydrological work may also be necessary to better define the range of certain environmental variables to increase the confidence that the geologic/hydrologic behavior is indeed accurately understood and therefore the chemicals are effectively controlled when immobilized, mobilized or treated in place.

Two cases in which remedial action recommendations are based on the demonstrated chemical immobility at a site are summarized below. Such remedial actions, based on a thorough evaluation of possible alternatives, are a practical and cost-effective approach to resolving site contamination issues.

CASE I: PCB Contaminated Soil and Groundwater

Problem - PCBs and solvents were codisposed to soils, and site investigation/remedial action evaluations were required by governmental agencies.

Site Investigation Results

- PCBs were generally found in top 1 foot of soil.

- PCBs had penetrated 20 feet into soil at one location, apparently due to codisposal of PCB with solvent.

- No solvents were found in groundwater, nor were TOCs levels in the waters particularly high; the solvents are readily degradable, so this finding was not unusual.

- No PCBs (<0.2 ppb) were found in numerous groundwater samples other than at the one site mentioned above.

- The site is in a semi-rural area with no immediate routes for human or environmental exposure (i.e., water wells, surface waters, dwellings).

Remedial Action Evaluation Efforts

- Literature survey and theoretical evaluation indicated PCBs are strongly partitioned to soil.

- Measurements of K_d by desorbing from contaminated soil gave values ranging from 100 to 1000.

- The velocity of PCB movement in groundwater is calculated to be on the order of 0.01 to 1 inch per year.

- Evaluation of remedial action alternatives resulted in recommendation that PCBs be left in place and that a clean soil cap be placed on site.

Rationale for Recommended Action

- PCBs are essentially immobile in site soil.

- Partitioning and dispersion of PCBs in groundwater will result in an insignificant loading of PCBs to any distant water body.

- Monitoring will continue to verify that PCBs are not mobile.

- Property owner is willing to keep property with restricted access.

CASE II: Lead (Pb) and Other Metals in Soil and Groundwater

Problem - Lead (Pb), iron (Fe) and zinc (Zn) were present in shallow groundwater, and property owner desired to sell property for light industrial use (warehouse and parking).

Site Investigation Results

- On-site groundwater samples generally contained dissolved Pb at or below detection limits (0.01 ppm), with dissolved Zn levels up to 1.0 ppm.

- One groundwater sample in an area of known high contamination (former sludge pond) showed Pb = 0.10 ppm, Zn = 0.21 ppm.

- Some waters contained dissolved Fe at high levels.

- Waters were generally of pH 8-9, and of moderate to high alkalinity.

- Some on-site groundwaters contained ammonia and cyanide.

- Off-site wells down-gradient of contaminated areas on the site showed pHs of about 7.2, and no detectable cyanide.

- A groundwater level contour was developed that showed two regions where groundwater is moving off-site.

- Groundwater moving off-site drains to an open ditch and eventually into a larger water body.

Remedial Action Evaluation Efforts

- A literature survey and calculations on the solubility of Pb species indicated that lead should not be mobile because of the high pHs of waters at the site.

- Addition of clean soils (from near off-site locations) to the most contaminated groundwater samples resulted in decreased concentrations of dissolved Fe and Pb in solution compared to the original solution.

- These efforts and the very low levels of Pb or Zn in off-site groundwaters show that these metals are not particularly mobile in groundwater.

- Evaluation of remedial alternatives now underway is focused on the conclusion that metals in on-site groundwater do not pose a threat for human and environmental exposure, and that minor clean-up efforts and addition of clean fill to the site will be sufficient for the property to be sold for light industrial use.

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REMEDIAL ACTION ALTERNATIVES: SLURRY TRENCHES AND GROUNDWATER EXTRACTION

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ABSTRACT

Two effective methods of containment and/or removal of groundwater contamination are low permeability barriers and groundwater pumping. Slurry trenches using a bentonite-backfill-water slurry are commonly used as a groundwater barrier. The barrier consists of a vertical wall of slurry material constructed underground to divert groundwater flow or minimize leachate generation and plume movement. Groundwater pumping usually involves extracting water to capture a plume or alter the direction of groundwater movement. Groundwater pumping is used when aquifer restoration is an issue. The combination of a groundwater extraction well system in conjunction with slurry wall barriers to contain the contaminant on site can be an effective remedial measure. Groundwater extraction systems, often used as a remedial measure for the contamination of the shallow aquifers in "Silicon Valley" by volatile organic compounds (VOCs) can be adequate as a remedial measure if the site conditions are appropriate. However, the heterogeneity of the sediments in the Silicon Valley area suggest slurry trenches may be an effective containment measure where the contaminated aquifer is shallow enough for its cost-effective application.

INTRODUCTION

General management options currently available for restoring water quality in aquifers include the following: (1) eliminate the source of contaminant but allow restoration to proceed only through natural flushing, dilution, and geochemical or biological reactions; (2) include in situ chemical or biological reactions that would neutralize or immobilize the contaminant; (3) accelerate flushing with artificial recharge;

(4) excavate and remove the contaminated part of the aquifer; (5) install "impermeable" cut-off wall barriers to contain a contaminated area; and (6) accelerate removal of contaminants through groundwater extraction wells, drain or trenches. This paper examines the two most common applications in the last two management options: slurry walls as a means of containment and groundwater extraction wells as a method of containment and removal of the contaminants.

The choice of an efficient and effective design technique to mitigate groundwater contamination requires an understanding of the medium through which the groundwater flows, knowing the spatial dimensions of the plume, the capability to predict the behavior of the chemical contaminants, and knowledge of the objectives and costs of the remedial action. Subsurface borings and hydrochemical characterization through monitoring well sampling helps define the geologic medium and contaminant plume geometry. The objective of the remedial action depends on the hazards or risks arising from the groundwater contamination. The choice of a particular remedial action technique, such as slurry or extraction wells, depends on their ability to meet the technical objectives and the costs/benefits associated with each technique.

SLURRY TRENCHES

Slurry cut-off walls are non-structural walls constructed underground to act as barriers to the lateral flow of water and other fluids. The principal application of slurry trenches in the control of contaminated groundwater in Santa Clara County is for site dewatering and pollution control.

Slurry cut-off wall techniques all involve excavating a trench which is kept filled with slurry, a mixture usually composed of bentonite, soil and water. The primary role of the slurry is to keep the trench open during excavation which may extend below the water table. Once a trench has been excavated under slurry to the required depth and length, it is backfilled to form a continuous, nearly impermeable barrier, or cut-off wall, to groundwater flow. In some cases, the slurry has cement added to the bentonite and water (CB backfill) which hardens in place to form the final barrier. The other common trench slurry technique used to place soil-bentonite (SB) walls is where the backfill is composed of the excavated soil with small amounts (1 to 4 percent) of bentonite added.

Materials and Applications

The material used in the trenching slurry is called bentonite, sodium bentonite, or Wyoming bentonite. Bentonite is considered a clay by many but is really a rock, composed chiefly of the clay mineral montmorillonite, with lesser amounts of other clays and metallic oxides. In addition, many of the commercially available bentonites are modified by the addition of polymers, peptizers, or other chemicals in order to

increase the amount of mud (slurry) yielded by lower grade bentonite deposits.

In order for the force exerted by the weight of the slurry to support the trench, the force must be exerted in the soil grains and not just on the soil pore fluids. Formation of a low permeability filter cake on the trench sides, caused by slurry and water loss from the trench into the ground, eventually seals off the soil pores, allowing the hydrostatic force of the slurry to be transferred directly to the sides. Permeabilities of filter cakes have been measured as low as 2.3 $\times 10^{-9}$ cm/sec (D'Appolonia, D.J., 1980; Spooner and Grube, 1983).

The permeability of the final wall is a function of both the filter cake permeability and the backfill permeability. Backfill permeability is dependent on the gradation of the soil used, as well as the bentonite content and initial water content of the backfill. Figures 1 and 2 show the relationships between permeability and bentonite fines and quantity, respectively. Bentonite can make up only a portion of the plastic fines in the backfill mixture due to its high compressibility. Thus the gradation of the backfill is a trade off between permeability and compressibility as illustrated in Figures 1 and 3.

An important consideration in evaluating the compatibility of slurry trenching for pollution control purposes is the potential reaction between the slurry and contaminant. The presence of organic or inorganic compounds in the groundwater can have a detrimental effect on the bentonite slurry used during the wall construction as well as the ability of the finished wall to contain pollutants. Thus, before a slurry wall is considered as an appropriate remedial response, the effects of the leachate on the bentonite slurry and on the finished wall must be determined through testing. Potential effects on the slurry properties from contaminants are flocculation of the slurry, reduction of bentonite's swelling capacity, and structural damage to bentonite or other backfill material. The effect which volatile organic compounds (VOCs) have on slurry is not known but is most likely limited to influencing the shrink/swell potential of the bentonite. Flocculation of bentonite slurry can be caused by metals or electrolytes which can reduce the natural repulsive forces between the hydrated clays. Structural damage is usually associated with strong acids or bases altering the bentonite or soil in the backfill material. Volatile organic compounds (VOCs) are not known to display either of the above properties (Moore and Remamoorthy, 1984).

The application of slurry walls for the purpose of pollution control is diverse, as indicated by Table 1. Costs of slurry walls per linear foot, also shown on Table 1, can vary significantly, depending on the type of pollutant being contained and other design factors. The composition, dimensions, and placement of the walls are, of course, designed on a site specific basis. The depth of the wall is most dependent on the behavior of the contaminant and the site stratigraphy. In

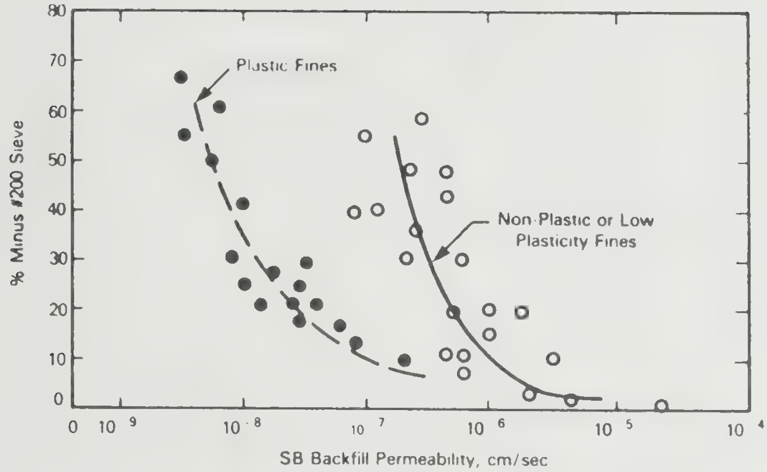

Figure 1. Permeability of Soil-Bentonite Backfill Related to Fines Content

(After D'Appolonia and Ryan 1979)

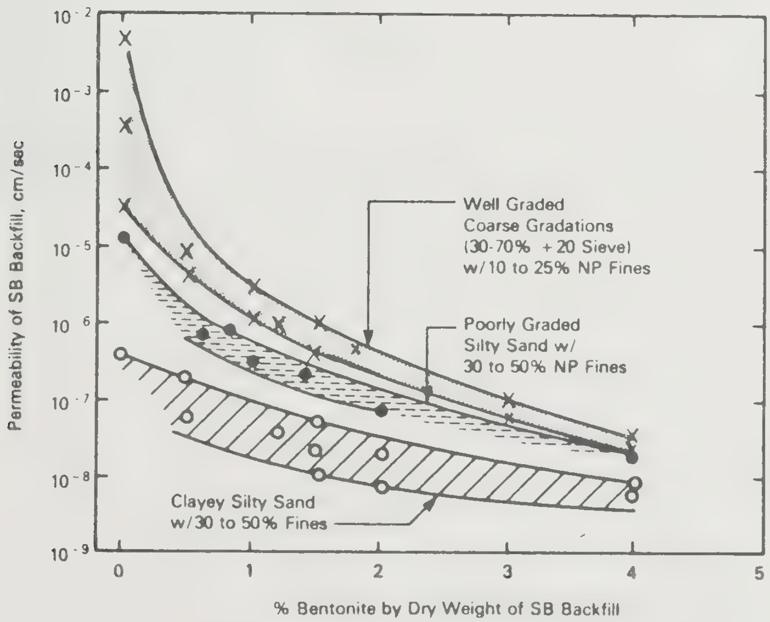

Figure 2. Relationship Between Permeability and Quantity of Bentonite Added to SB Backfill

(After D'Appolonia and Ryan 1979)

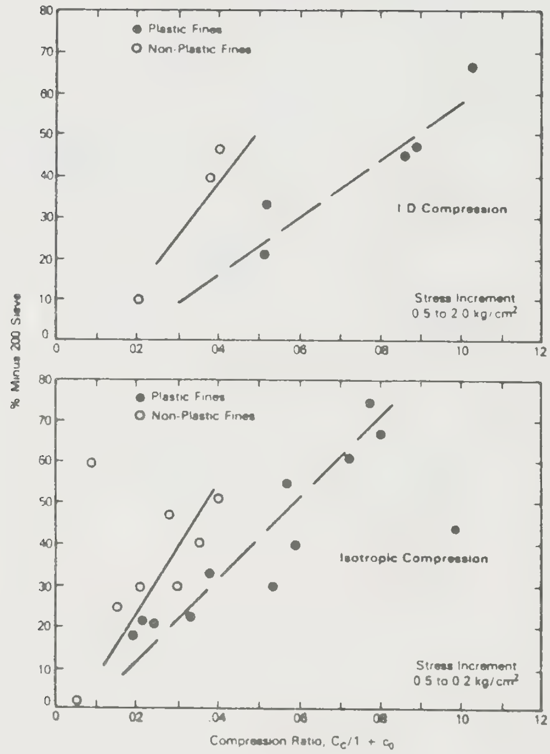

Figure 3. Compressibility of SB Backfill Related to Fines Content of Mix

LOCATION	WALL COMPOSITION	SIZE* (ft.^{2} x 1000)	APPROXIMATE COST ($/ft.^{2})	POLLUTANT CONTAINED	STATUS
Indiana	Soil-Bentonite	500	3	Inorganics Ash Disposal	On-going
Illinois	Soil-Bentonite	13.5	4	Methane Gas	Completed
Louisiana	Soil-Bentonite	30	2.5	Ethylene Dichloride	Completed
Pennsylvania	Cement-Bentonite	1	2	PCB Oils	Completed
New York	Cement-Bentonite	77.3	5.5	Jet Fuel	Completed
New Hampshire	Soil-Bentonite	204	5	Mixed Organics	On-going
Wisconsin	Soil-Bentonite	98.4	2.8	Solid Waste Landfill Leachate	Completed
New Jersey	Soil-Bentonite	10	6	Phenols	Completed
Saskatchewan	Soil-Bentonite	53.4	4	Uranium Mill Tailings	Completed
Florida	Soil-Bentonite	58	2.6	Methane Gas Landfill Leachate	Completed
Ohio	Soil-Bentonite & Cement-Bentonite	25	10	Acid Mine Drainage	Completed
Florida	Cement-Bentonite	10	4	Radioactive Kerosene	Completed

*These walls range from 2 to 4 feet in width and 15 to 100 feet in depth.

TABLE 1. Example Slurry Walls Installed For Pollution Control (after Spooner & Grube, 1983)

most situations, it is necessary to key the wall into a low permeability strata underlying the contaminated aquifer. This is true in the case of contaminants by VOCs such as trichloroethylene and trichloroethane associated with the semiconductor industry. Aquitards between contaminated aquifers in the South Bay region make keying-in possible.

The length and shape configurations of a slurry wall are mainly dependent on the location of the pollutant source and any resultant contamination plume, as well as the intended role of the wall. Generally, a wall can be placed surrounding a source, or upgradient or downgradient from the source with respect to groundwater flow.

Placement of the slurry wall upgradient of the contaminant plume protects the groundwater upgradient of the contaminant source, diverting the groundwater around the source. Where upgradient drains are included to divert groundwater flow around a contaminated area, the cut off increases assurance that the pollutant is isolated from adversely affecting water quality. Figure 4 illustrates upgradient placement and barrier drain combination.

Downgradient placement can be used in situations where the amount of flow into a source is very low. This situation, as illustrated in Figure 5, utilizes the slurry wall to capture the contaminated groundwater plume so that it can be collected and treated. Care must be taken to ensure that no destructive effects on the wall from the contaminant occurs or that the contaminant does not overtop the wall. This is the best approach to take in the cases such as VOC contaminants of significant proportions where there is no question of treatability, only how it is to be performed.

Slurry walls are rarely used as the sole type of engineering remedial measure. However, they may be very valuable when used in conjunction with groundwater pumping.

WELL SYSTEMS

Groundwater extraction systems are generally used in conjunction with methods for intercepting or cutting off the flow of groundwater in areas where aquifer restoration is called for. Aquifer treatment and restoration is usually required by regulatory agencies when the contaminants are both toxic enough to be of concern and mobile enough to migrate offsite or to deeper aquifers. Effective extraction well system design necessitates having at least a groundwater monitoring program, and elimination of the identified contaminant sources such as a leaky underground storage tanks, etc.

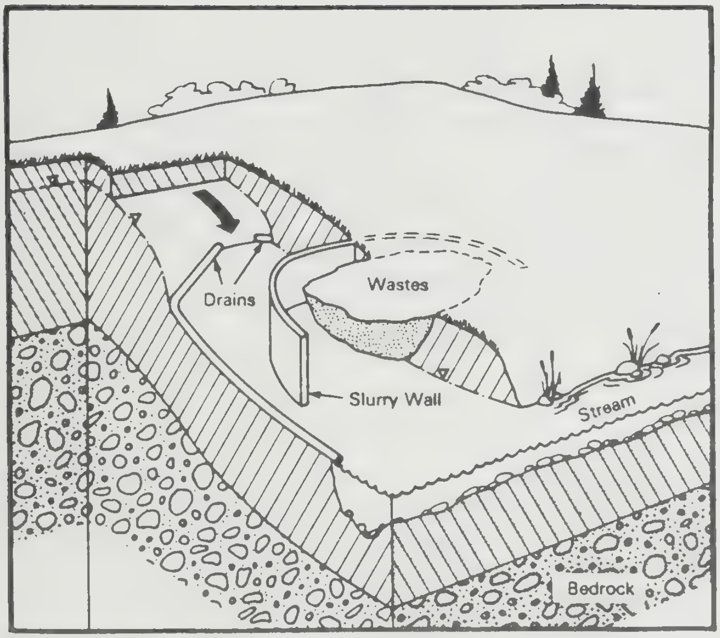

Figure 4. Cut-away Cross-section of Upgradient Placement with Drain (after Spooner & Grube, 1983)

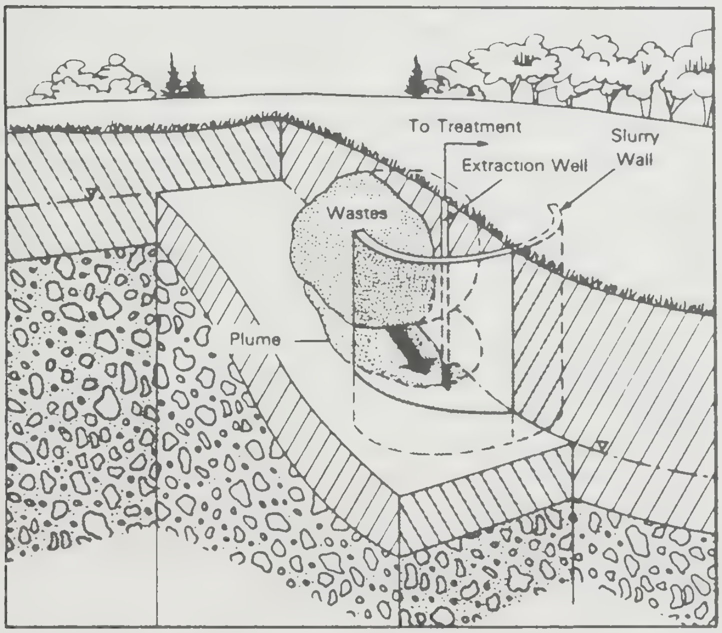

Figure 5. Cut-away Cross-section of Downgradient Placement (after Spooner & Grube, 1983)

Well Design and Installation

The design of an appropriate well system for the specific site and contaminant requires that adequate information on the site's hydrogeologic conditions and plume geometry be available. There are four principal types of wells used in plume management: well points, suction wells, ejection wells, and deep wells (Kufs et al., 1983). Table 2 lists selection criteria for these well types. Using the site data, selection of an appropriate well type can be made. In the case of groundwater contamination by VOCs in the aquifers underlying the South Bay areas which have extended to greater than 50 feet below the ground level, the selection of "deep" wells is normally used.

Applications

The groundwater extraction well system can be designed to perform several functions with or without the assistance of slurry barrier walls or other technologies. The main applications in plume management are groundwater level adjustment, plume containment, and plume removal. How valid the assumptions of extrapolating like materials at like depths laterally between well logs where site geology is highly variable. A geophysical survey of the site can often provide a cost-effective solution in such site conditions (Kufs et al., 1983).

The ultimate "restorability" of a contaminated aquifer is dependent on the hydrogeologic and geochemical properties of the contaminant. Restoration of a contaminated aquifer is neither technically nor economically feasible in some cases. Factors frequently hindering restoration include (1) the slow diffusive nature of groundwater flow, (2) the difficulty of defining secondary permeability effects, (3) the generally low oxygen content and lack of biological reactivity in groundwater, (4) the retention of some chemicals in the aquifer because they tend to be sorbed by minerals (mainly fines) in the aquifer (5) the lack of transferability of some restoration techniques from one site to another; and (6) the lack of knowledge about the source of the contaminants. Restoration of shallow aquifers contaminated with VOC's, however, appears to be feasible.

Hydrologic modeling of the groundwater system can be a rapid method in evaluating and comparing the effectiveness of various pumping strategies that alter future migration of contaminants. Numerous models, both analytical and numerical, are available for plume delineation and extraction system evaluation (Boonstra and de Ridder, 1981). These models are ultimately only as good as these data that go into them. A comparison of the advantages, disadvantages, and examples of data obtained using different plume delineation methods are shown on Table 3. Removal techniques are suitable when contaminant sources have been stopped (e.g., by waste removal or site capping) or contained (e.g., by barrier walls) and aquifer restoration is desired. Numerous patterns and arrays for injection and extraction wells can be used depending on the site

TABLE 2 CRITERIA FOR WELL SELECTION

Parameters	Wellpoints	Suction Wells	Ejector Wells	Deep Wells
Hydrology				
o Low permeability (e.g., silty or clayey sands)	Good	Poor	Good	Fair to Poor
o High permeability (e.g., clean sands and gravel)	Good	Good	Poor	Good
o Heterogeneous materials (e.g., stratified soils)	Good	Poor	Good	Fair to Poor
o Proximate recharge	Good	Poor	Good to Fair	Poor
o Remote recharge	Good	Good	Good	Good
Depth of Well	Shallow < 20 ft	Shallow < 20 ft	Deep > 20 ft	Deep > 20 ft
Normal spacing	5-10 ft	20-40 ft	10-20 ft	> 50 ft
Normal range of capacity (per unit)	0.1-25.0 gpm	50-400 gpm	0.1-40.0 gpm	25-3000 gpm
Efficiency	Good	Good	Poor	Fair

(After Powers, 1981)

TABLE 3. SUMMARY OF PLUME DELINEATION METHODS

Methods	Advantages	Disadvantages	Examples of Data Obtained
Hydrogeologic Investigations	• The primary method of obtaining site data needed for remedial action design and implementation	• Can be very expensive • Can be fairly hazardous to investigators • Does not provide much information on plume dimensions	• Aquifer characteristics (e.g., gradient, transmissivity, storage coefficient) • First hand evidence of wastes and leachate effects
Geophysical Investigations	• Fairly inexpensive and safe method of obtaining site data	• Data is sometimes ambiguous	• Areas of high/low groundwater conductivity/resistivity
Geophysical Investigations (Continued)	• Can provide data on both site geology and plume dimensions • Can provide continuous as well as discrete data	• Techniques can be depth limited at some sites	• Locations of buried drums (metal detection, magnetometer) • Site geology (i.e., lithology, stratigraphy, structure)
Groundwater Sampling	• The primary method of obtaining data on plume dimensions	• Can be fairly expensive • Can be hazardous to investigators • Discrete data points are sometimes difficult to interpret	• Concentrations of individual chemicals or chemical groups at specific locations and depths at a site
Hydrologic Modeling	• A fairly rapid method of assessing site data in great detail • Can be fairly inexpensive depending upon the model chosen • A variety of computer models exist for data analysis	• Requires a fairly extensive amount of high quality data • Data output must be evaluated in terms of input data accuracy and precision and assumptions • Requires field and analytical verification • Answers are only estimates of actual conditions.	• Present and future plume movement patterns • Effects of site remediation alternatives on plume dynamics

(Modified after Kufs et. al, 1983)

specific conditions. Extraction/injection techniques may also be used in conjunction with flushing compounds to accelerate contaminant removal. As with containment designs, treatment of pumped water is necessary.

SILICON VALLEY EXAMPLE

The regional hydrogeologic setting of many of the Silicon Valley semiconductor industry is along what is referred to as the west side alluvial apron. This is a gently sloping alluvial sequence between the San Francisco Bay to the east and the coastal hills to the west. The sequence is composed of distal portions of alluvial fans which interfinger with a central outwash plain. This plain was deposited by ancestral creeks draining the highlands to the south. Periodic invasions by ancestral San Francisco Bay have modified the continental environment. The alluvium is generally more fine-grained to the north, towards the bay. Groundwater flow is generally from south to north.

The site-specific hydrogeologic environment is fairly characteristic of the regional setting. Groundwater flow is generally from south by southwest to north by northeast. Local heterogeneities in the permeability of sediments (e.g., sand- and gravel-rich, water-bearing channel versus fine-grained overbank deposits) may locally modify the dominant flow direction. Braided channel deposits have flowed across the landscape for millions of years, some being interconnected and some found as isolated lenses. The transgressions and regressions associated with the water level fluctuations in the San Francisco Bay may account for some of the discontinuities seen in the deeper sand sequences in the area. Recharge to the three identifiable shallow aquifers beneath the site is both from underflow from the alluvial apron and from direct infiltration of rainfall or stream flow. The contaminated aquifers, generally at 10 to 15, 20 to 35, and 45 to 60 foot depths, are usually a few feet in thickness and separated by clay rich aquitards while all three aquifers show some contamination by the greatest concentration of VOCs is in the uppermost sands.

The design of an extraction wells system in such a variable hydrogeologic environment is not a simple matter of assuming isotropic hydrogeolic conditions and computing the equilibrium radius of influence. Monitoring well pumping test have shown the hydraulic properties of the aquifers vary significantly with up to an order of magnitude variation in the hyrdaulic conductivity of a given aquifer.

In this type of situation, where the radius of influence if an extraction well is not easily predicted and where regulatory concern with the contaminants are such that aquifer restoration is being required, the effectiveness of limiting offsite migration of the contaminated groundwater can be increased with the use of barrier walls. The barrier wall, such as a slurry trench, combined with the groundwater pumping system can be used to trap contaminated groundwater and then pump it to a treatment system.

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STRATIGRAPHIC INFLUENCE ON CLEAN-UP METHODS: A CASE HISTORY

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ABSTRACT

To be effective, clean-up methods for subsurface organic solvent contamination must be designed for site-specific soil and groundwater conditions. At the site under investigation, a leaking buried tank containing waste solvents was excavated in April 1981. Groundwater occurs between depths of 25-30 feet within low permeability soils, and an effluent creek is located 200 feet down-gradient of the leak. During site characterization, a 3-6 feet thick clay layer was identified five feet below the water table in the plume area. Chemical test results showed that this clay layer substantially retards downward solvent migration, and that most of the percolation from the unsaturated soils into groundwater had already occurred.

Therefore, the primary clean-up objective was to prevent lateral solvent migration down-gradient to the creek within the thin groundwater unit above the confining clay layer. After consideration of more costly alternatives, the standard "pump and treat" approach was modified to accommodate extremely low flow conditions and the 5-foot limit on drawdown cone depth. Solvent concentrations are reduced prior to surface discharge by wet impingement scrubber treatment. A cone of depression large enough to contain the plume was developed after six months of continuous pumping. Monitoring results demonstrate that solvent concentrations in groundwater have been significantly reduced by three years of clean-up operations.

EFFECT OF SITE STRATIGRAPHY ON SOLVENT MIGRATION

The facility under investigation is located in the San Francisco Bay Area in foothills near the margin of a gently sloping alluvial

plain. The natural topography in the site vicinity consists of rolling hills and swales with an overall relief of approximately 200 feet. A narrow meandering stream crosses the northwestern portion of the property, as shown on Figure 1A.

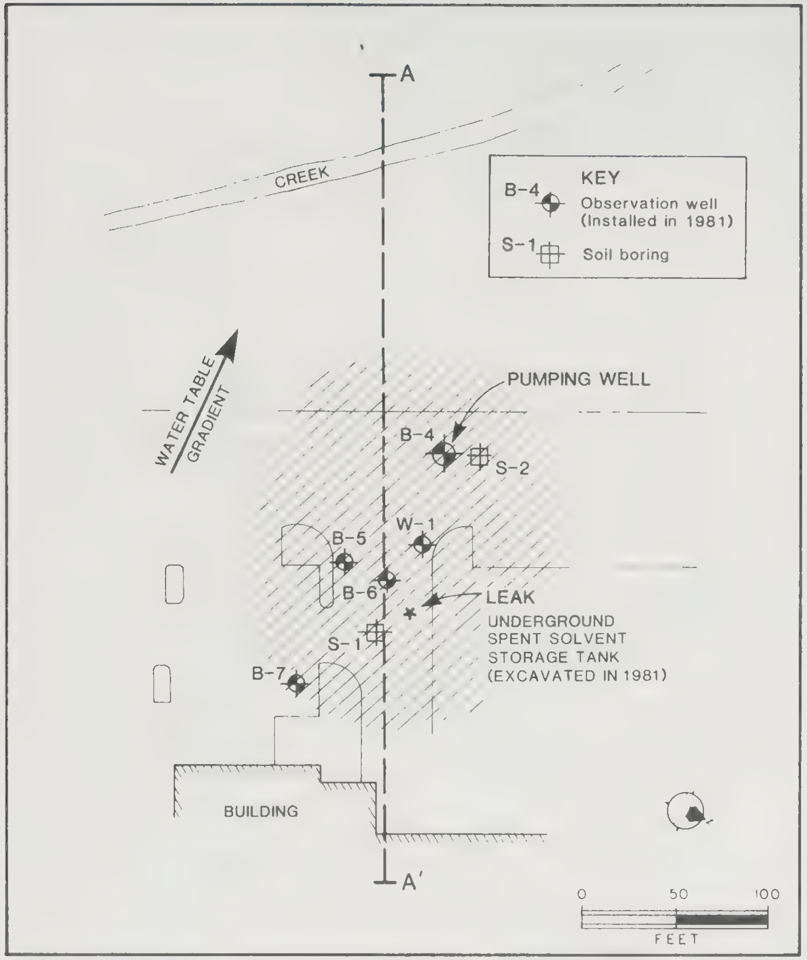
The natural site topography has been modified by cut and fill operations associated with construction of buildings and parking lots. In general, the hills in the northeastern portion of the site were cut, and fill was placed in the southwestern section overlooking the creek to form a gently sloping building site. A steep slope descends approximately 20 feet from the southwestern edge of the parking lot fill to the narrow creek flood plain below.

A phased subsurface contamination assessment was performed to evaluate the extent of a subsurface solvent leak in site soils and groundwater. Subsurface conditions were investigated by means of observation wells, soil borings, soil and water sampling, and chemical analysis. A total of 13 shallow observation wells and two deep soil borings have been installed and sampled since 1981. The source of the solvents was a 2,000 gallon capacity subsurface spent solvent storage tank. Total solvent discharge during time of service was 1 to 2 gallons per week; leakage is estimated to have occurred during a period of about two years before the tank was excavated in April 1981.

Hydrogeologic Setting

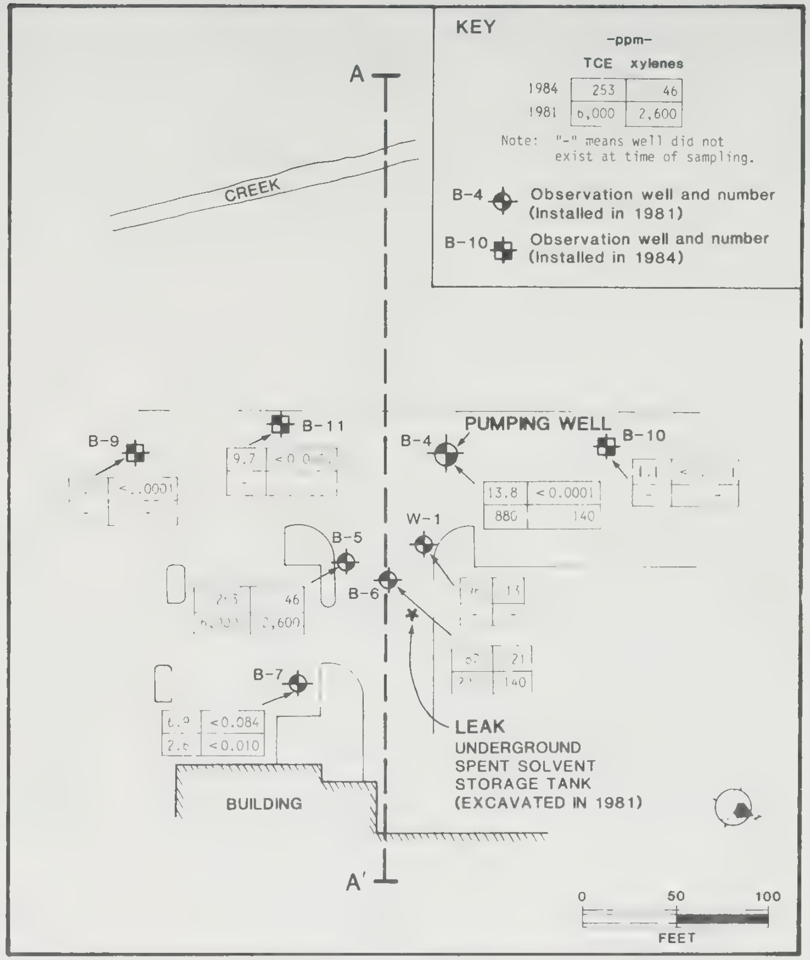
The site is located in rolling foothills that form the margin of the Santa Clara Valley groundwater basin. Most of the developed industrial sites in the vicinity are located within the adjacent valley, where a thick sequence of alluvial sands and silts has been developed for water supply. A common approach to groundwater clean-up within the valley is to pump contaminated groundwater for surface treatment. In this area, sandy units produce yields in the range of 10-200 gpm (gallons per minute), and the standard submersible pumps typically used for water supply wells can be easily adapted for clean-up operations.

Although the site under investigation is located only a few miles from the adjacent valley sites, the geology of the upland area is very different from the valley geology. The valley groundwater basin consists of a series of structural troughs which formed as blocks of Miocene bedrock gradually downdropped along nearly parallel faults in the valley floor. These troughs in the bedrock surface were filled with alluvial fan deposits which washed down from the surrounding hills and gradually coalesced. It is the unconsolidated alluvial valley fill along with the underlying Santa Clara Formation which form the major water-producing units. Both the alluvial valley fill and the Santa Clara Formation consist of highly variable alluvial fan deposits, which range from silty clays and silty sands to gravels. The Miocene marine bedrock occurs at depths of 100 to 600 feet. It is generally of low permeability and often contains saline connate water.



ZONE OF GROUNDWATER CONTAMINATION
(BEFORE PUMPING)

FIGURE 1A



DECREASE IN SOLVENT CONCENTRATIONS IN GROUNDWATER
(AFTER THREE YEARS OF CONTINUOUS PUMPING)

FIGURE 1B

In the upland area, bedrock is exposed at the surface in the hills which surround the site. The swales between the hills are filled with a much thinner accumulation of continental slope wash and stream deposits. Although groundwater occurs within these sediments, extensive sandy aquifer units do not exist in this environment. Thus, groundwater clean-up methods appropriate for valley sites must be modified in the uplands.

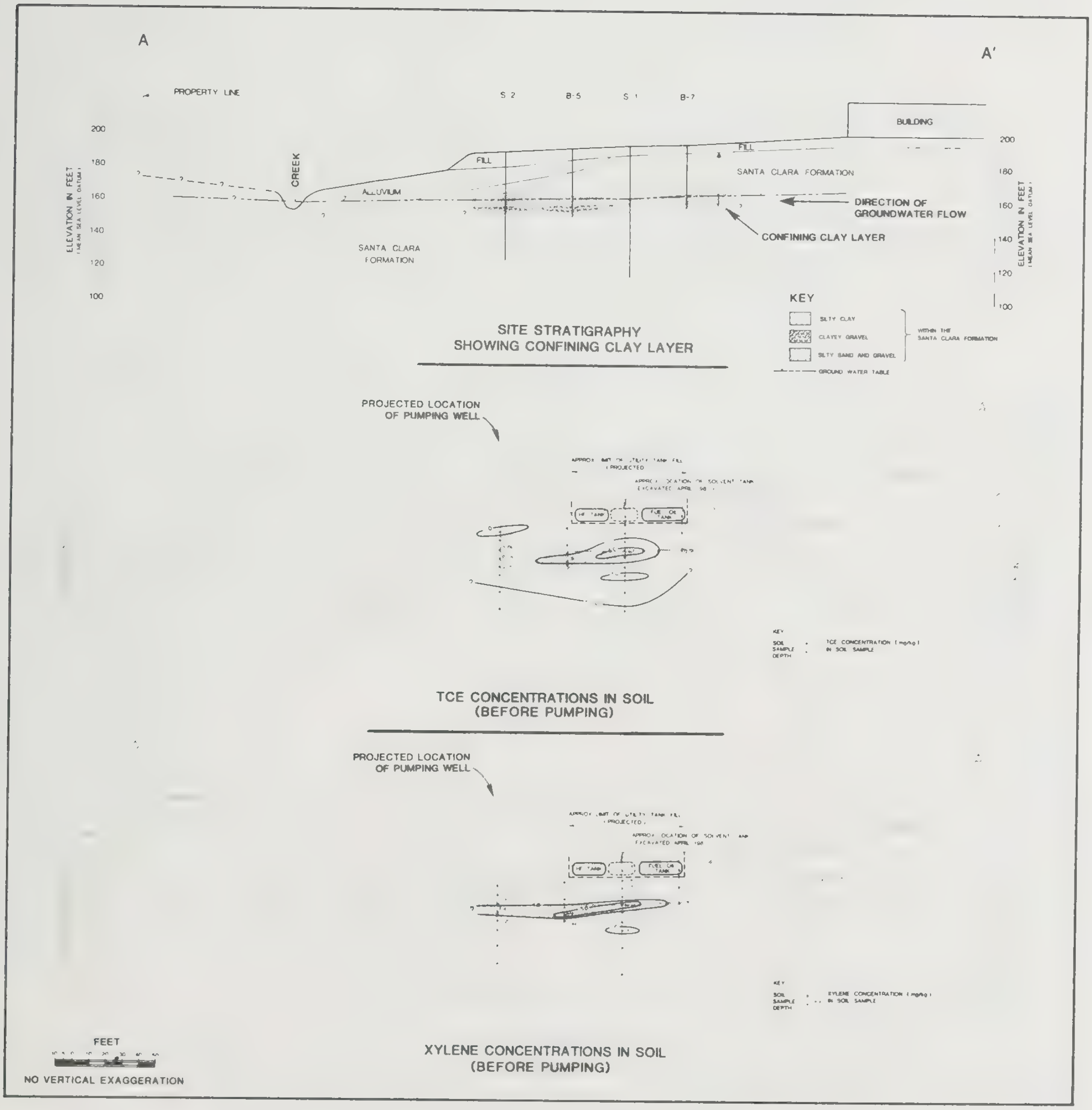
Site Subsurface Conditions

The configuration of the solvent plume at the site is strongly influenced by the subsurface site stratigraphy. Overall, the soils in the leak area consist of predominantly low permeability silty clays and silty sands which mantle the irregular Tertiary bedrock surface. In general, the developed portions of the site are underlain by 5 to 10 feet of fill, with the greater thicknesses occurring along the western edge of the parking lot. Below the westernmost portion of the parking lots, the fill is underlain by 4 to 10 feet of alluvial terrace deposits, which consist of silty clays interbedded with silty sands. This alluvium is limited to the portion of the site adjacent to the creek.

The fill and the alluvium, where present, are underlain by the continental Santa Clara Formation. This heterogeneous unit consists of crudely interbedded sands, silts, gravel and clays. The continental deposits are underlain by Miocene marine sandy siltstone and silty sandstone bedrock, which is also exposed at the surface in construction cuts adjacent to the facility buildings.

In general, the water table surface tends to mirror surface topography, but in a more subdued configuration. At the site, groundwater occurs within the Santa Clara Formation (or within bedrock under the hills) between depths of 25-40 feet below ground. In the solvent leak area, groundwater occurs at about 30 feet, and the water table gradient slopes from the leak area west toward the small effluent creek 200 feet away. At the water table, soils consist of silty sands and gravel. About 5 feet below the water table, a 3-6 feet thick clay layer occurs below the silty sand, as shown on Figure 2. The soils below the clay layer consist of interbedded silty clays and silty gravel. The clay layer appears to act as a barrier to vertical water and contaminant movement. Laboratory tests showed extremely low vertical permeabilities ranging from 8.4×10^{-9} to 4.7×10^{-8} cm/sec.

In-situ permeability was evaluated in the thin water table zone above the clay layer by means of rising head permeability tests conducted in wells completed at the top of the clay layer. These wells draw water only from the saturated soils above the clay. Calculated horizontal permeability in this zone was low, ranging from 2.7×10^{-5} cm/sec to 5.1×10^{-4} cm/sec. A relatively higher value of 1.4×10^{-3} cm/sec was measured at the down-gradient well subsequently used for pumping (well B-4).



SCHEMATIC SUBSURFACE CROSS SECTION A–A'

FIGURE 2

Solvent Distribution in the Subsurface

The solvents which leaked from the tank included trichlorethylene (TCE) and xylenes, neither of which is water soluble. Because the specific gravity of this mixture is greater than 1, the solvents would tend to sink through the groundwater in the direction of flow unless confined by a low permeability barrier.

At the site, solvent concentrations in the contaminated area increase with depth through the unsaturated soil zone above the water table, reach maximum levels within sandy soils below the groundwater table and above the clay layer, and decrease to trace levels below the clay. In general, the solvent concentrations within a particular depth interval decrease with distance from the former tank. This distribution pattern of TCE and xylenes in soils is summarized in Table 1 and is illustrated on Figure 2.

TABLE 1

SOLVENT CONCENTRATIONS IN SOILS
ABOVE AND BELOW THE CONFINING CLAY LAYER

Boring	Distance from tank	TCE (mg/kg) Above (30-36')	TCE (mg/kg) Below (40-46')	TCE (mg/kg) Below (50-56')	XYLENES (mg/kg) Above (30-36')	XYLENES (mg/kg) Below (40-46')	XYLENES (mg/kg) Below (50-56')
S-1	10 feet	6.7	0.44	0.11	7.1	0.77	0.15
B-5	35 feet	1.6	0.02	-	5.9	0.46	-
S-2	65 feet	0.54	0.49	<0.01	2.4	0.27	0.05

GROUNDWATER CLEAN-UP UNDER LOW FLOW CONDITIONS

Conclusions Affecting Clean-Up Program Design

1. Solvent concentrations in groundwater were higher than in soils above the water table, and the solvents appeared to be moving down-gradient with the groundwater toward the creek.

2. The asymmetrical groundwater contamination plume was about 5 feet thick and extended at least 65 feet down-gradient of the leak. The up-gradient radius was about 50 feet, and lateral extent was at least 50 feet from the tank.

3. Downward solvent migration was significantly retarded by natural site conditions, so that clean-up operations could be limited to the thin water-bearing zone above a natural clay barrier. Horizontal permeabilities within this zone are low and range between 2.7×10^{-5} cm/sec and 1.4×10^{-3} cm/sec, reflecting the varying clay content of the soils below the water table.

Remedial Action Options Considered

1. Excavation and removal of contaminated soil and water.
2. Containment by slurry cut-off wall.
3. Extraction well with off-site disposal.
4. Extraction well with on-site treatment.
5. Extraction by french drain with subsequent treatment and/or disposal.
6. In-situ treatment by biological degradation.

Optimum Clean-Up Program: Extraction Well with On-Site Treatment

The most cost effective groundwater clean-up program for site conditions features pumping the contaminated water to the surface followed by wet impingement scrubber aeration treatment to reduce solvent concentrations to acceptable levels prior to discharge into a city sewer system. The success of pumping operations depends on the development of a cone of depression in the water table, shown schematically on Figure 3. This drawdown cone contains the contaminated groundwater and prevents further contaminant migration toward the creek by altering the groundwater gradient in the contaminated zone so that the water and entrained contaminants would flow toward the pumping well.

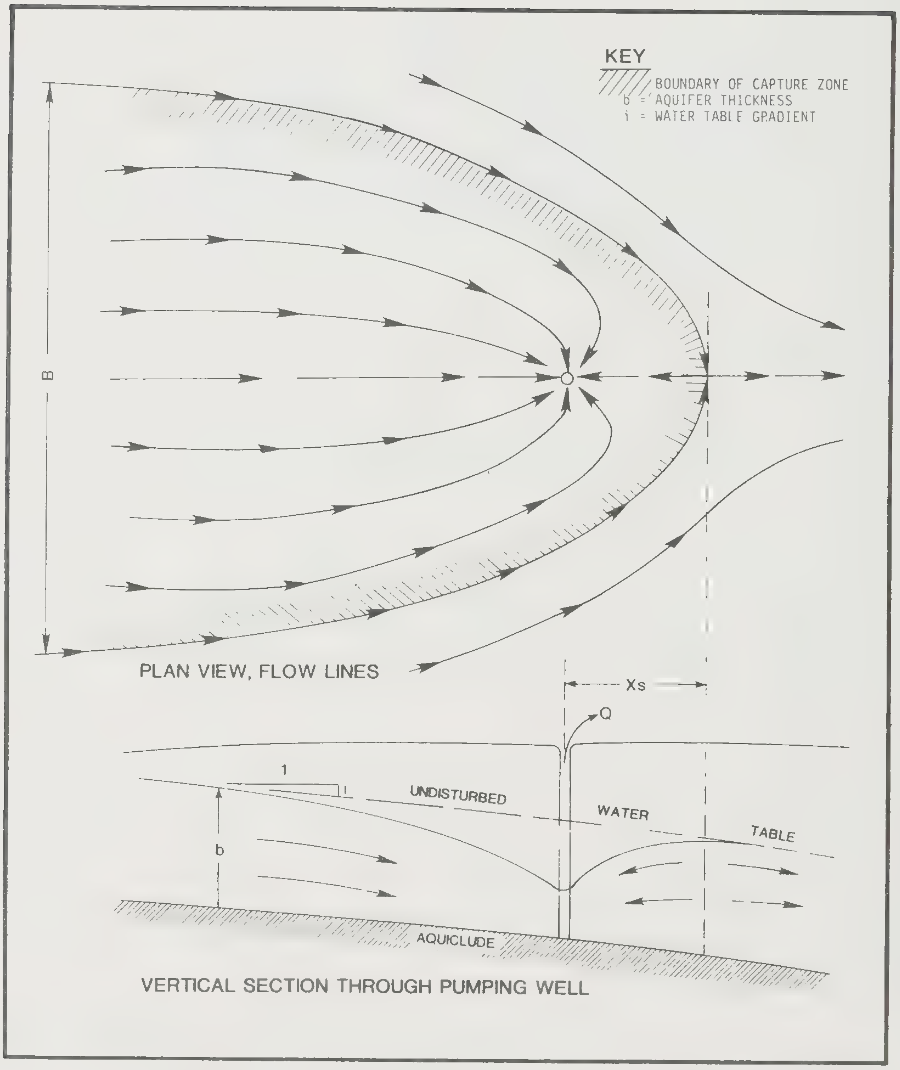
However, pumping operations are the site are severely constrained by low well yield. The wells at the site were completed only 5 feet below the water table in order to avoid penetrating through the low permeability clay layer. Therefore, drawdown in the pumping well is limited to about 4 feet below the water table. The combination of small available drawdown and low permeability of the water table aquifer results in a very low groundwater yield to the pumping well. This creates two problems:

1. It is difficult to keep standard pump equipment designed for higher flow rates operating; and

2. The fully developed drawdown cone may not be large enough to capture the entire zone of contamination.

Technical Feasibility of Pumping Under Low Flow Site Conditions

In order to evaluate whether a pumping approach would be effective under these low flow conditions, measured water table aquifer properties were used to calculate the following aquifer response to pumping:



WELL IN UNIFORM FLOW
SHOWING FULLY DEVELOPED DRAWDOWN CONE

FIGURE 3

1. Predicted sustained flow rates from aquifer pumping would be very low. A calculated value of 0.1 gpm was used in further calculations.

2. Aquifer response to pumping would be extremely slow. A period of at least 3 to 6 months would be required to develop a drawdown cone sufficiently large to be observed in the monitoring wells at the site.

3. The calculated dimensions of the fully developed capture zone would extend about 50 feet down-gradient of pumping well B-4 (well B-4 is 65 feet down-gradient from the tank location). The up-gradient width of the zone of intercepted groundwater would be about 300 feet, depending on the heterogeneity of the site soils.

4. The size of the capture zone described in Item 3 would not be significantly affected by variations in pumping flow rates. This is because the drawdown in the well is fixed at about 4 feet, and thus the pattern of groundwater flow toward the well depends primarily on the ratio of well discharge to aquifer permeability. If the aquifer permeability were to double, then the well discharge would double at the same time, so that the dimensions of the capture zone would be about the same as at the lower permeability and flow rate.

Results of this analysis indicated that the capture zone developed from pumping well B-4 would be sufficiently large to intercept the contaminants in the groundwater below the site, and that additional pumping wells would probably not be required.

Implementation of Groundwater Pumping Operations

A circulating jet pump was installed to accommodate the anticipated low flow conditions instead of the submersible pump commonly used in this type of clean-up operation. When maximum sustained flow rates in the initial pumping well stabilized at the extremely low rate of 0.1 gpm, the pump was transferred to observation well B-4, located 65 feet down-gradient of the excavated tank. The measured field permeability in this well was 1.4×10^{-3} cm/sec, high relative to other wells at the site. After three weeks of extremely low yield, this well began producing a sustained flow of 0.4 to 0.5 gpm. The pump has been operating continuously since October 1982.

The pumped water flows through an existing 76,000 cfm (cubic feet per minute) facility scrubber to reduce solvent concentrations to acceptable levels prior to discharge into a municipal sewer system. The flow streams are tested on a regular basis to ensure compliance with city concentration limits for sewer discharge.

RESPONSE OF THE WATER TABLE AQUIFER TO PUMPING

A groundwater table contour map illustrating the water table configuration prior to pumping is shown on Figure 4; the cone of depression induced by pumping from well B-4 is shown on Figure 5. Although the limits of the cone of depression developed by pumping from well B-4 cannot be defined exactly, it is clear that drawdowns of 2 to 3.5 feet below normal static water table are well developed in the area of the leak. Theoretical analysis indicates that this drawdown cone should be sufficiently large to contain and recover contaminants in the groundwater at the site.

Regular testing indicates that solvent levels in groundwater are decreasing with time. The areal distribution of the TCE and xylene concentrations measured in 1981 and 1984 are shown on Figure 1B. The overall pattern of solvent distribution in groundwater has not changed significantly since 1981. At B-7, an up-gradient well located near the former tank, xylenes were not detected in either year, and TCE is present at relatively low levels. These solvents are present in the wells down-gradient of the former tank, with the highest levels measured at well B-5. However, the TCE and xylene concentrations in this area have decreased substantially from 1981 levels. TCE levels decreased from 290 to 87 mg/l at well B-6 and from 6,000 to 253 mg/l at well B-5. Xylenes show a similar decrease, from 140 to 21 mg/l at well B-6 and from 2,600 to 46 mg/l at well B-5. The maximum width of the plume based on information from wells down-gradient of the former tank is about 200 feet.

SUMMARY

At the site under investigation, solvents in groundwater are present in a 5-foot thick water table zone above a low permeability clay layer. Because the clay layer limited the extent of the solvent plume by retarding vertical migration, groundwater clean-up could be limited to the thin water table zone above the clay. However, the combination of small available drawdown and the low permeability of the water table aquifer resulted in a very low yield of 0.1-0.5 gpm to the pumping well. A groundwater pumping program modified for low flow conditions was implemented in January 1982. Although groundwater response to pumping is extremely slow, pumping operations have resulted in significant reductions in solvent concentrations in groundwater below the site. It is likely that additional pumping will continue to be an effective means of groundwater clean-up.

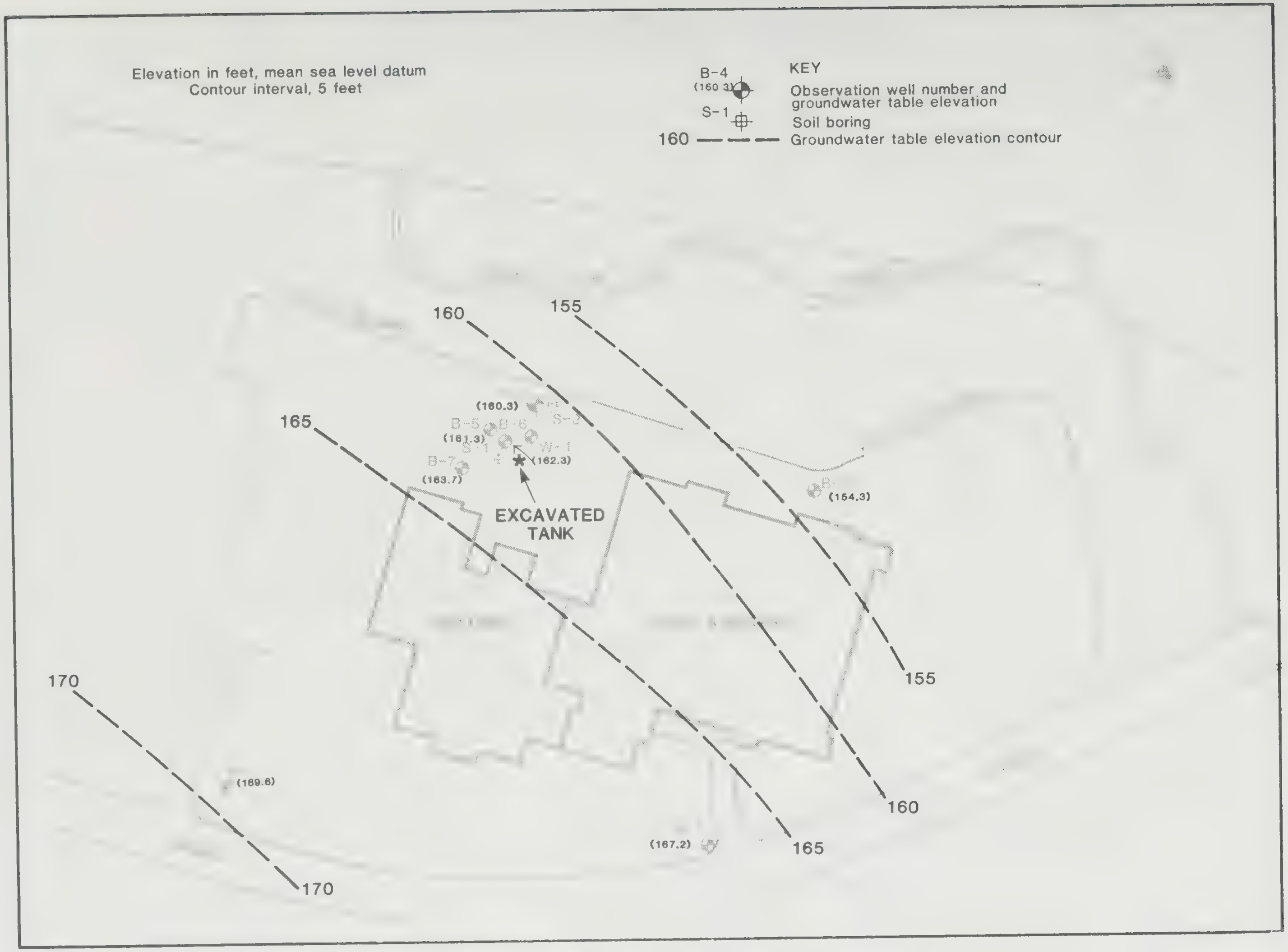


FIGURE 4 **GROUNDWATER TABLE CONTOUR MAP**
(BEFORE PUMPING)

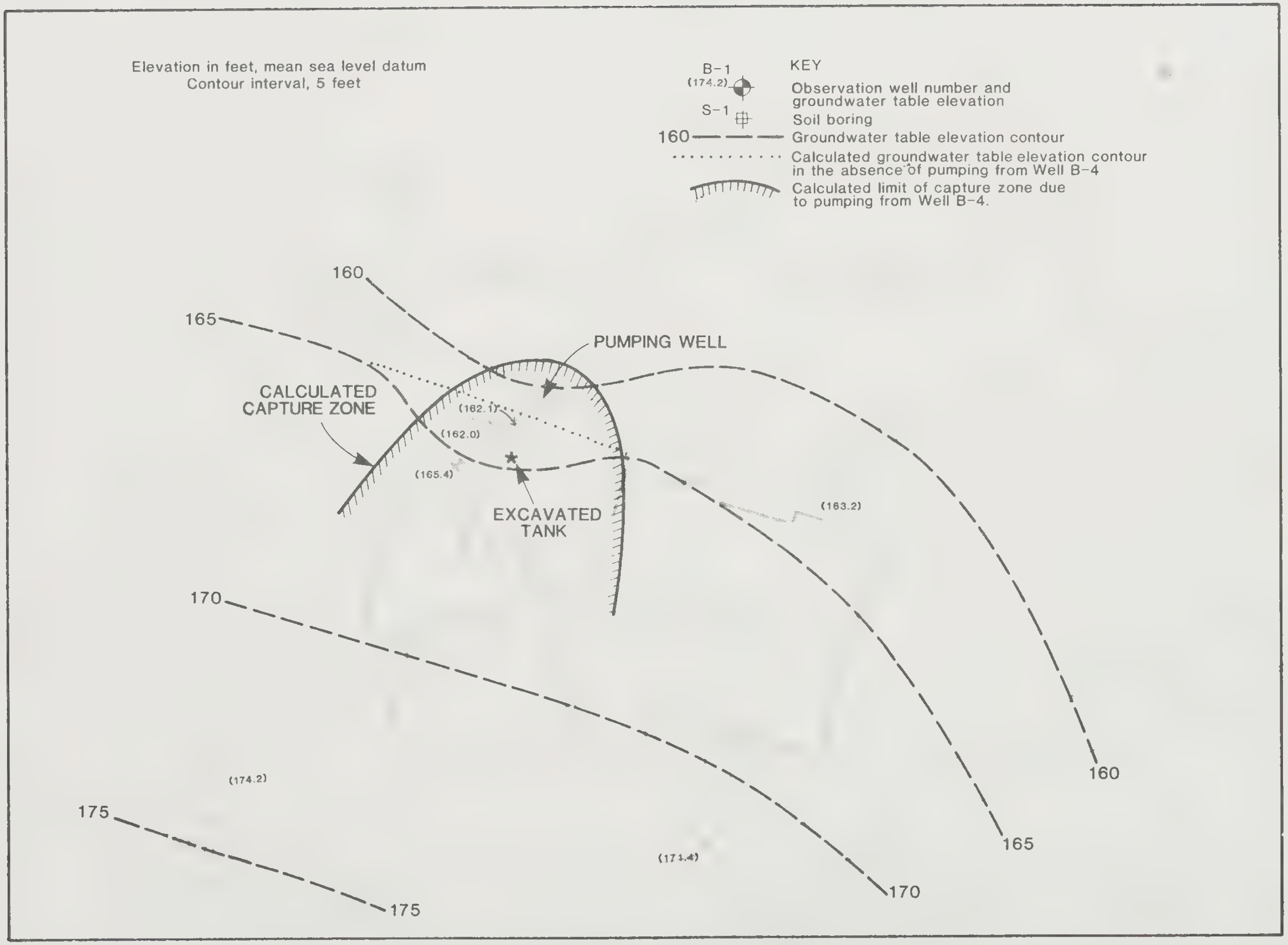


FIGURE 5 **GROUNDWATER TABLE CONTOUR MAP**
(AFTER SIX MONTHS OF CONTINUOUS PUMPING)

BIOLOGICAL CLEANUP OF CHEMICAL SPILLS

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Introduction

On site biological cleanup following spills of biodegradable hazardous organic compounds in lagoon, soil, and ground water environments is a cost-effective technique when proper engineering controls are applied (Environmental Reporter, 1983; Flathman, et al., 1985; Flathman and Githens, 1985; Flathman, et al., 1984; Flathman, et al., 1983). Biodegradation of hazardous organic contaminants by microorganisms (Kobayashi and Rittmann, 1982) minimizes liability by converting toxic reactants into harmless end products.

The two case histories presented describe:

1. Bench-scale evaluation of the potential for biological cleanup in the spill site matrix
2. Field implementation
3. Removal rates of contaminants at the spill site

O.H. Materials Co. has performed biological cleanups of spilled substances since 1978, when a railroad incident resulted in spillage of acrylonitrile. Subsequent biological environmental restoration projects have included additional acrylonitrile spills and other materials such as crude oil, petroleum hydrocarbons, butylcellosolve, ethylacrylate, toluene, n-butylacrylate, methylene chloride, styrene, acetone, isopropanol, tetrahydrofuran, and various phenolics.

Cost-effectiveness, minimal disturbance to existing operations, on-site destruction of spilled contaminants, and permanence of solution are several of the advantages identified for implementing biodegradation as a technique for spill cleanup and environmental restoration.

Case History No. 1: Biological Treatment of Phenolic Compounds at a USEPA Superfund Hazardous Waste Site Using Land Treatment Techniques

Introduction

Biological techniques were used successfully to cost-effectively remove recoverable phenolic compounds from contaminated soil at the Picillo Farm, a USEPA superfund hazardous waste site in Coventry, Rhode Island. By completion of the project, land treatment techniques resulted in removal of an estimated 1500 pounds of recoverable phenolics in 1700 cubic yards of soil initially contaminated with an estimated 1700 pounds of recoverable phenolic compounds. This represented an 88 percent reduction in the recoverable phenolics content of the soil, a value 39 ppm below the project goal of 100 ppm.

In the fall of 1977, an explosion and fire at the Picillo Farm led to the discovery of an estimated 10,000 buried drums of hazardous wastes. In 1978, the Rhode Island Department of Environmental Management initiated a major cleanup effort at the Picillo Farm. A site investigation revealed the presence of four discrete trenches containing buried drums. Beginning in the summer of 1980 and continuing through 1982, three discrete evacuation phases took place. During those phases, 2300, 4500, and 3300 drums of hazardous wastes were excavated, sampled, analyzed, and composited for off site disposal.

Approximately 1700 cubic yards of hazardous soil remained on site. An initial analysis indicated the soil was highly contaminated with phenol and contained detectable levels of m-tert-butylphenol and p-1,1,3,3-tetramethylbutylphenol. The full spectrum of substituted phenolic compound contamination was not initially realized. For the purpose of evaluating more environmentally beneficial and cost-effective disposal options compared to secure landfill disposal, the Rhode Island Department of Environmental Management requested an approach for biodegrading the spilled contaminants.

Biodegradation of phenolic compounds has been well documented. Tabak, et al., (1981) demonstrated that phenol and the chlorinated, as well as the nitrated, USEPA priority pollutant phenolics (with the exception of 4,4-dinitro-o-cresol) were biodegraded under aerobic conditions. Gibson (1984) reviewed the published literature describing the biochemistry and regulation of aerobic and anaerobic biodegradation of aromatic compounds, including the phenolics. Anaerobic biodegradation of phenolic compounds in a creosote-contaminated ground water environment has been established (Ehrlich, et al., 1983; Ehrlich, et al., 1982). Horowitz, et al., (1982) described anaerobic biodegradation of aromatic compounds, including phenolics, in sediments and digested sludge.

Biofeasibility Evaluation

Prior to initiation of the feasibility study, the following screening analyses were performed on a composite soil sample collected from the site: total recoverable phenolics, ammonia-nitrogen, and orthophosphate concentrations, pH, aerobic heterotrophic bacterial populations, and percent moisture.

The analytical procedures used for sample analysis are summarized as follows:

1. Total Recoverable Phenolics. The soil sample was analyzed colorimetrically to quantify the total recoverable phenolics present using USEPA procedures (USEPA, 1979). Method 420.3 was used for analysis.

2. Ammonia-Nitrogen and Orthophosphate-Phosphorus. Ammonia-nitrogen (NH_3-N) and orthophosphate-phosphorus (PO_4-P) were quantified spectrophotometrically by nesslerization and ascorbic acid, respectively (Hach Chemical Company, Ames, Iowa).

3. pH. Soil pH was determined by electrode analysis using a 1:1 ratio of soil:water.

4. Aerobic Heterotrophic Bacterial Populations. Bacterial enumeration was performed using standard plate count procedures (Bordner, et al., 1978). Samples were processed using membrane filtration and standard plate count agar. Incubation was at $20 \pm 1^{o}C$ for 48 ± 3 hours.

5. Percent Moisture. Moisture content was calculated as a percentage of the oven-dry weight of the soil following drying at $110^{o}C$ to constant mass (Pramer and Schmidt, 1964).

Results of the screening analyses indicated a total recoverable phenolics concentration of 880 ppm in the soil. The soil contained a viable microbial population (geometric mean = 1.4×10^5 CFU/g oven-dry soil, n = 2). The NH_3-N and PO_4-P concentrations were 98 and 64 ppm, respectively. Ammonia-nitrogen is assimilated quickly during microbial growth and is required in quantities approximately ten times greater than orthophosphate-phosphorus (Mitchell, 1974). Soil moisture content was 10.3 percent and soil pH was 9.3. The optimum pH for growth generally lies between 6.0 and 7.0 with minimum and maximum values of 4.4 and 9.0, respectively (Atlas and Bartha, 1982). Therefore, pH adjustment of the soil was required.

The feasibility study was performed using the electrolytic respirometer (Exidyne Instrumentation Technologies, Inc., Colorado Springs, CO) which provided a direct and continuous measurement of oxygen uptake by microbial populations within closed reaction vessels (with oxygen generated within the closed system). Oxygen uptake by microbial aerobic heterotrophs is a direct measurement of biodegradation taking place within the reaction mixture.

Respirometer vessels were prepared using the composite soil sample. With reference to Table 1, vessels 1 and 2 were replicates demonstrating the feasibility of biodegrading the recoverable phenolics. The inoculum control (vessel 3) would quantify oxygen uptake resulting from the microbial inoculum and nutrient addition. Comparison of oxygen uptake rates in vessel 4 with vessel 5 would demonstrate the presence of significant quantities of substances toxic or inhibitory to microbial growth. Vessel 4 contained 50.0 g (wet weight) of the composite soil sample while vessel 5 received 10 ml of a 1% (wt/vol) soil suspension. Nonbiological loss of the

recoverable phenolics was initially considered as a separate treatment. Due to laboratory safety considerations, the recoverable phenolics were not quantified in the abiotic control; hydrogen cyanide would have been produced in an acidification step of the chemical procedure.

TABLE 1. TREATMENTS FOR ELECTROLYTIC RESPIROMETER BIODEGRADATION STUDY.

VESSEL NUMBER	TREATMENT
	BIOLOGICAL AUGMENTATION
1, 2	SOIL SAMPLE + INOCULUM OF COMMERCIAL MICROBES
	INOCULUM CONTROL
3	INOCULUM OF COMMERCIAL MICROBES
	TOXICITY / INHIBITION CONTROL
4	SOIL SAMPLE + GLUCOSE
5	GLUCOSE + SOIL MICROBIAL INOCULUM

Respirometer vessels were prepared using procedures described by Young and Baumann (1976) with diammonium phosphate and sodium dihydrogen phosphate added to each culture vessel. A suspension of the commercially available Type R-5 microbes from Flow Laboratories, Inc. (Inglewood, CA) was used to augment several treatment vessels. The Type R-5 microbes were a mixture of bacterial strains selected for their ability to biodegrade phenolics and other aromatic compounds.

Throughout the study, aliquots (10 ml) were periodically removed from respirometer vessels and analyzed for pH, and for NH_3-N, NO_3-N, and PO_4-P, which were sources of inorganic nitrogen and phosphorus required for microbial growth. When necessary, pH and inorganic nitrogen and phosphorus concentrations were adjusted to ensure that the chemical environment remained favorable for microbial growth.

Electrolytic respirometer oxygen uptake data for vessels 1 and 2 are presented in Figure 1. The ultimate BODs (BODµ) for respirometer vessels 1 and 2 were determined by subtracting the inoculum control (vessel 3) and fitting the corrected oxygen uptake data to a modified crescent curve (Shammas, 1983):

$$y = a + be^{-kt}$$

where,

- y = the amount of BOD expressed or exerted at time t (ppm)
- a = the ultimate amount of oxygen uptake to be expressed (ppm)
- b = a lag period parameter (ppm). (Note: b = a if the fitted crescent curve intersects the origin)
- k = the rate constant ($hour^{-1}$)
- t = time (hours)

Ultimate BOD is defined as the total amount of oxygen required to biodegrade the immediately available organic matter present in a sample (Mitchell, 1974).

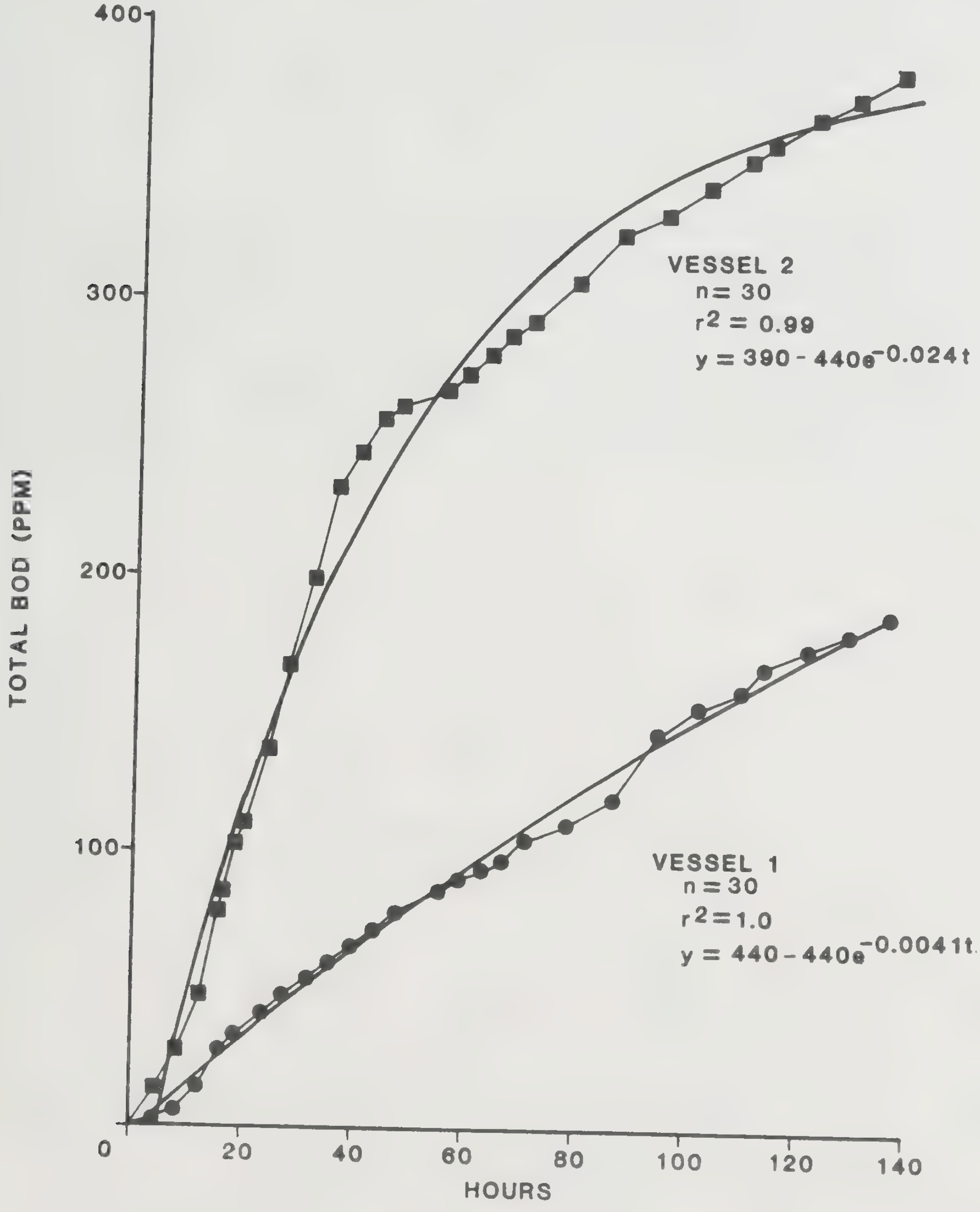

Figure 1. Electrolytic respirometer oxygen uptake data for replicate soil samples.

Table 2 presents biodegradation data for total recoverable phenolics. Based on an initial value of 880 ppm, respective reductions for vessels 1 and 2 in 6.5 days were 36 and 66 percent. An explanation for the variable rates in oxygen uptake could not be given. However, the ultimate BODs for both vessels were similar, indicating that comparable total recoverable phenolics reductions could be expected.

TABLE 2. TOTAL RECOVERABLE PHENOLICS BIODEGRADATION IN REPLICATE ELECTROLYTIC RESPIROMETER VESSELS.

	TOTAL RECOVERABLE PHENOLICS (PPM) DAY 0	DAY 6.5	REDUCTION (%)	BOD_u (PPM)	RATE CONSTANT, k (DAY^{-1})	r^2
VESSEL 1	880	560	36	440	0.098	1.0
VESSEL 2	880	300	66	390	0.56	0.99

As evidenced by oxygen uptake rates in the toxicity/inhibition control (Figure 2), the soil did not appear toxic or inhibitory to microbial growth. At the termination of the study, initial oxygen uptake data in the toxicity/inhibition control (i.e., vessels 4 and 5) were compared. On a semi-log plot, a comparison was made of the slopes of the lines-of-best-fit through the linear portion of the natural log tansformed oxygen uptake data. In the linear portion of the semi-log plot, the rate of oxygen uptake in the glucose-containing composite soil sample was 1.2 times greater than in the glucose control.

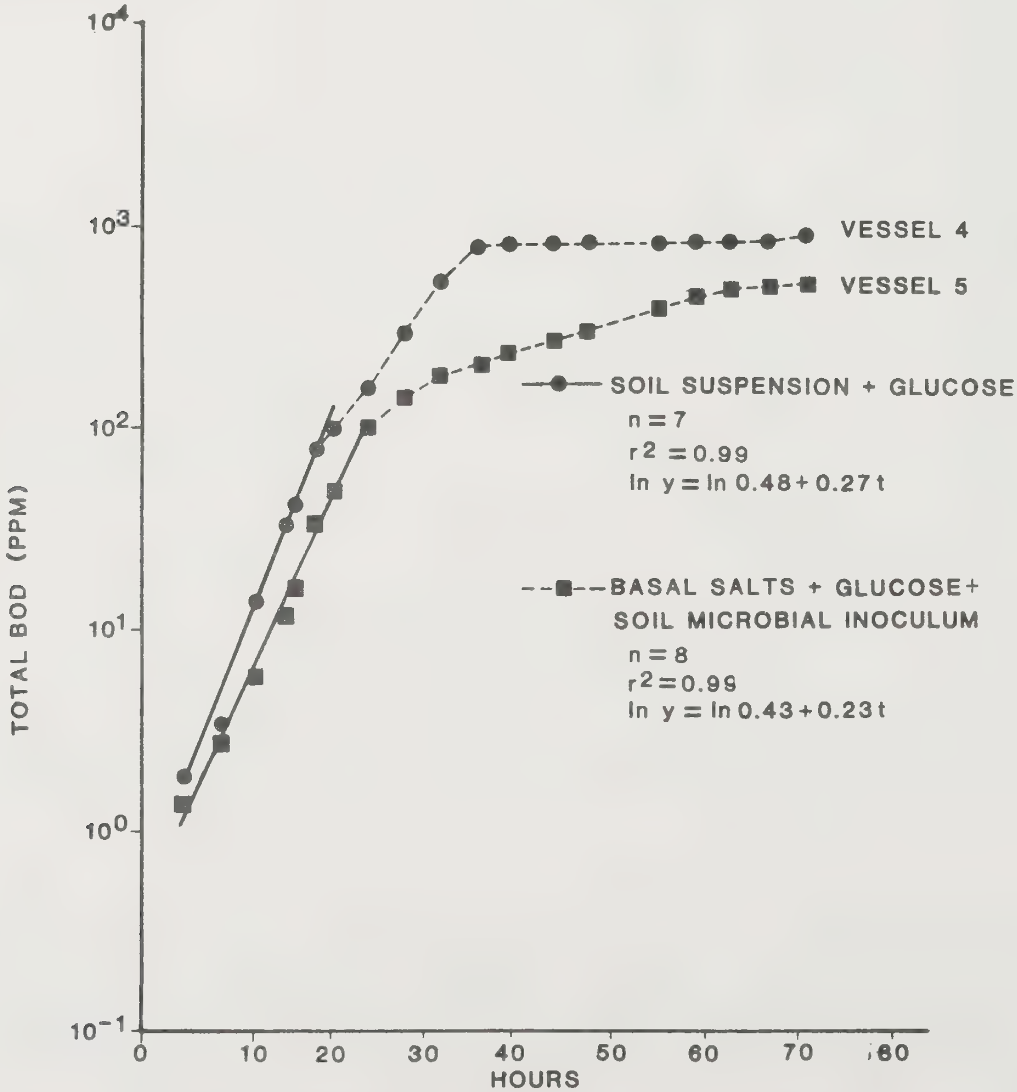

Figure 2. Electrolytic respirometer oxygen uptake data for a soil sample containing glucose and for a glucose control.

Evaluation of feasibility study results indicated that biodegradation techniques were a viable option for reducing the recoverable phenolics content of the soil. When compared to the other options that had been considered, such as secure landfill disposal, interceptor trenches, site encapsulation, etc., biological treatment was more cost-effective. Therefore, a land treatment program utilizing biological techniques was initiated at the site.

Field Implementation

A schematic of the treatment system used at the site is presented in Figure 3. Control measures used to prevent migration of contaminants from the site included a two-foot dike around the perimeter of the cell, two heat-sealed impermeable visqueen liners separated by 6 inches of clean sand, a leach field consisting of perforated polyvinyl chloride (PVC) pipe with a gravel pack, and a gravity-fed 50,000 gallon pool to collect and treat water for recirculation. The 1700 cubic yards of sandy loam phenolics-contaminated soil was farmed to an average depth of 18 inches in the three-quarter acre secure cell.

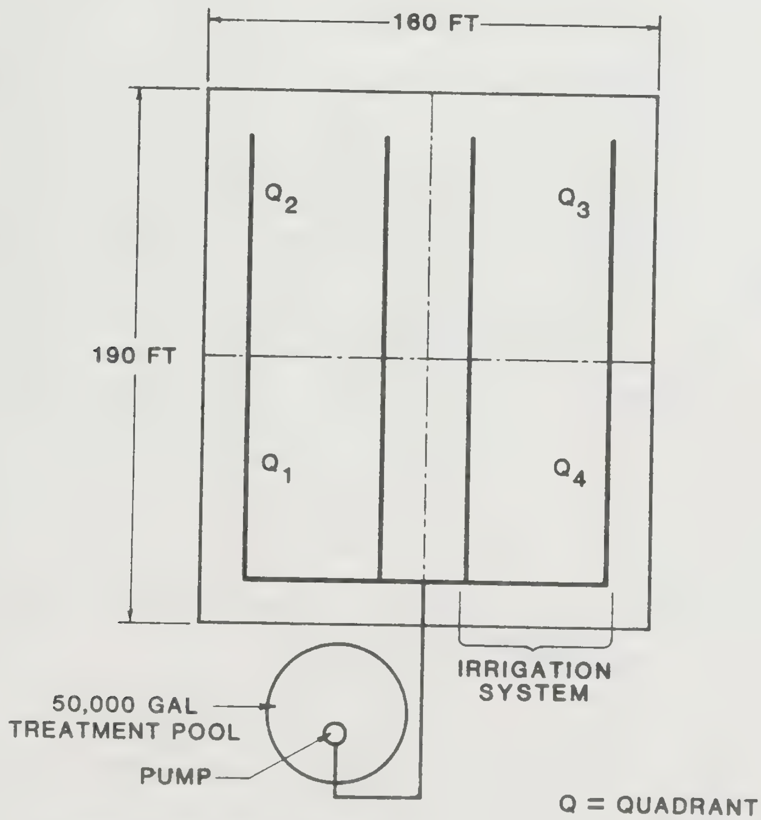

Figure 3. Treatment system schematic.

Generally, greater rates of biodegradation occur in an aerobic environment. Through frequent tilling, the soil was maintained in a loose condition necessary for maintenance of aerobic conditions. Maximum development of aerobic organisms takes place when the soil moisture content is about two-thirds of the water holding capacity (Pramer and Schmidt, 1964). Moisture

content was maintained within 60 to 80 percent of the moisture holding capacity of the soil via periodic pumping from the 50,000 gallon treatment pool. Inorganic nitrogen and phosphorus concentrations plus pH were adjusted to favorable ranges for bacterial growth. The soil was tilled and a mixture of commercially available bacterial strains was seeded into the soil to increase bacterial population density.

On a weekly basis, eight soil cores were randomly collected from each of the four quadrants and a composite from each quadrant was analyzed for total recoverable phenolics, pH, NH_3-N, NO_3-N, PO_4-P, percent moisture, and aerobic heterotrophic bacteria. Based on the results of those analyses, environmental parameters were modified to maintain an effective rate of biological treatment.

Three distinct phases of phenolics removal rates were observed (Figure 4). Recoverable phenolics reduction was rapid during the first phase (i.e., the first 13 days) of biological treatment with a weekly reduction rate in the soil approximating 150 ppm (Table 3). This was equivalent to 480 pounds of recoverable phenolics removed per week from the soil.

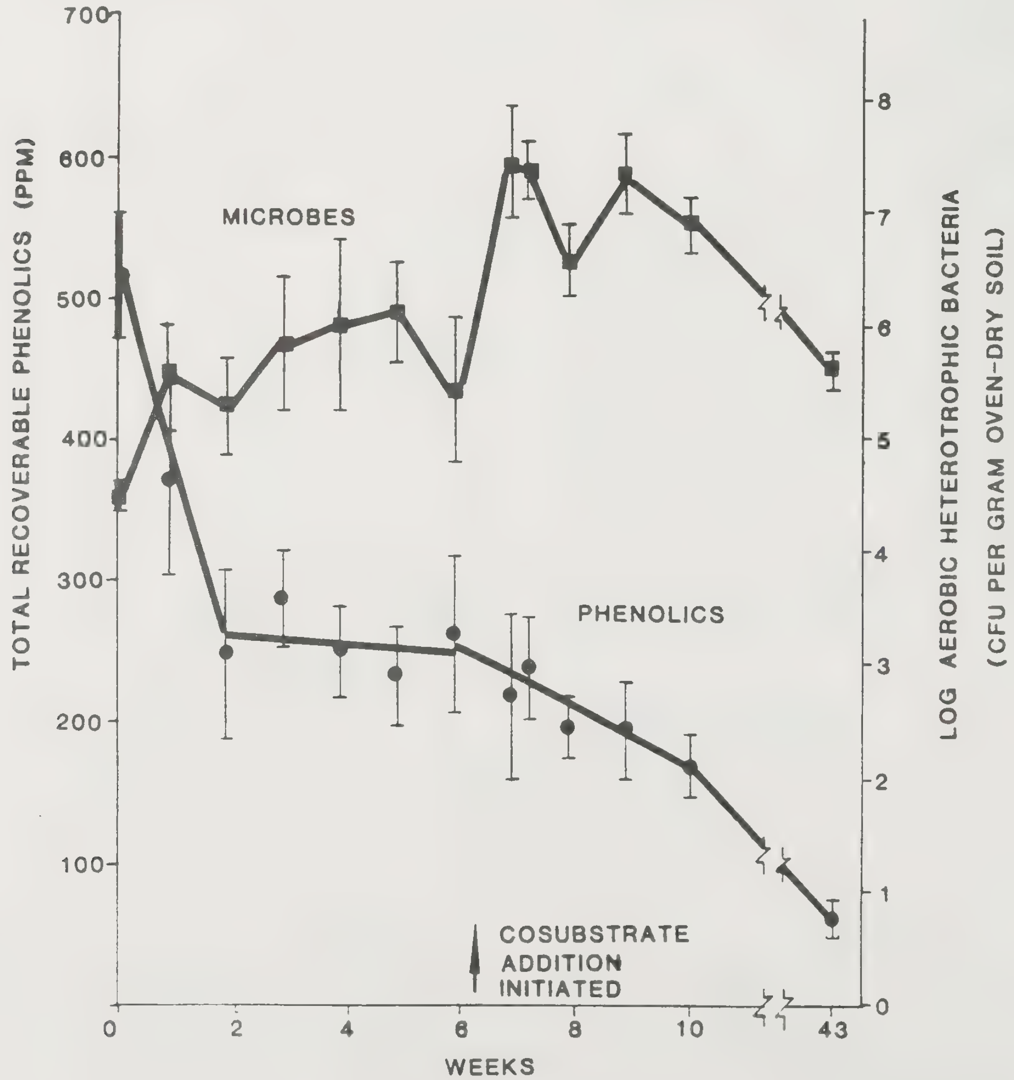

Figure 4. Total recoverable phenolics concentration and bacterial population density in land farmed treatment area as a function of time.

TABLE 3. REDUCTION RATES FOR TOTAL RECOVERABLE PHENOLICS.

	REDUCTION RATE (PPM/WEEK)
LAND FARMED TREATMENT AREA	
DAY 0-13 (PHASE 1)	-150
DAY 13-41 (PHASE 2)	-3.7
DAY 41-70 (PHASE 3) COSUBSTRATE ADDITION	-21
SOIL BOX CONTROL	
DAY 13-41 (PHASE 2)	+0.43
DAY 41-70 (PHASE 3)	-0.70

The second phase of treatment (i.e., days 13-41) was marked by a significant reduction in the phenolics removal rate from the soil. Reduction rates had changed from 150 to 4 ppm per week. This was equivalent to a removal rate of 13 pounds per week.

Cosubstrate addition, initiated in third treatment phase, resulted in a six-fold increase in the removal rate of recoverable phenolics. For cometabolized contaminants (Alexander, 1981; Beam and Perry, 1974; Horvath, 1972a; Jacobson, et al., 1980), addition of an appropriate cosubstrate can significantly increase the biodegradation rate (Horvath, 1972b; Horvath, 1973; Horvath and Koft, 1972; Horvath and Flathman, 1976, Sethunathan and Pathak, 1971). Cometabolism is defined as the oxidation of substances without utilization of the energy derived from the oxidation to support microbial growth (Horvath, 1972a). Although participation of cometabolism was not clearly demonstrated in this project, enhancement of the recoverable phenolics biodegradation rate with cosubstrate addition suggests the existence of a cometabolic process in the system.

When temperatures dropped below freezing on day 70, treatment was terminated. At that point, total recoverable phenolics concentration was only 68 ppm above the previously established objective of 100 ppm in the soil. On day 304, results of sampling analyses revealed that the mean total recoverable phenolics concentration had been reduced to 61 ppm, a value significantly below the established goal for the project.

In situ destruction of the phenolic compounds in the soil environment using biological treatment techniques provided an estimated cost benefit of $70,000 (a 30 percent savings) when compared to the cost of secure landfill disposal. This was based on estimated transportation and disposal costs of $230,000 and the actual job cost of $160,000. With biological treatment of greater soil volumes, proportionally greater cost benefits would be realized. In addition to the cost benefit achieved, future liability was minimized as a result of on-site destruction of the phenolics in the soil environment.

Case History No. 2: Biological Treatment of Ethylene Glycol-Contaminated Ground Water at Naval Air Engineering Center, Lakehurst, New Jersey.

Introduction

At the Naval Air Engineering Center in Lakehurst, New Jersey, biodegradation techniques successfully treated ethylene glycol-contaminated ground water following the loss of an estimated 4,000 gallons of cooling water from a lined surface storage lagoon. The cooling water was estimated to contain 25% (vol/vol) ethylene glycol.

The problem developed on January 5, 1982, following a liner break. A subsequent investigative program confirmed soil contamination around the lagoon and identified a 180 foot long by 45 foot wide contaminant plume extending to the east. At the start of the project, mean ethylene glycol concentration in the ground water was 1,440 ppm. Approximately 85 to 93 percent of the ethylene glycol was removed from the ground water within the first 26 days of biological treatment. By the completion of the project, ethylene glycol was reduced to below the limits of detection (LOD = 50 ppm) in all production wells at the site.

Biofeasibility Evaluation

The biofeasibility study assessed the biodegradation potential of ethylene glycol in the spill site matrix as well as the presence of a toxic or inhibitory environment to microbial growth. In addition, techniques to increase the biodegradation rate in the spill site matrix were also evaluated. Such techniques commonly include the use of surfactants, cosubstrates, primary substrates, vitamins, trace elements, and selected microbial strains. The results of the biofeasibility evaluation form the basis for subsequent field implementation, as discussed in this case history.

Ethylene glycol can be used as a carbon and energy source for aerobic microorganisms (Clause and Hempel, 1970; Fincher and Payne, 1962; Gonzalez, et al., 1972; Thelu, et al., 1980). The aerobic metabolism of ethylene glycol is relatively common, and the pathways of its metabolism are known (Caskey and Taber, 1981; Child and Willetts, 1978; Harada and Nagashima, 1975; Jones and Watson, 1976; Pearce and Heydeman, 1980; Thelu, et al., 1980; Wiegant and DeBont, 1980; Willetts, 1981). Caskey and Taber (1981) demonstrated that the most likely pathway of ethylene glycol catabolism by bacterium T-52 was sequential oxidation of glycolate and glyoxylate. By reaction with acetyl-CoA, glyoxylate would form malate, a Krebs Cycle intermediate.

Anaerobic metabolism of ethylene glycol has been reported by Dwyer and Tiedje (1983). Using a sewage sludge inoculum under methanogenic conditions, ethylene glycol was converted to ethanol, acetate, and methane. The ethanol produced was further oxidized to acetate with methane as the final end product. Clostridium glycolicum fermentation of ethylene glycol has been shown to yield equimolar amounts of acetate and ethanol (Gaston and Stadtman, 1963). The metabolism of ethylene glycol by a Flavobacterium under microaerophilic conditions follows the sequence: acetyl-CoA, acetylphosphate, and acetate (Willetts, 1981). Thus, ethylene glycol mineralization can occur in both aerobic and anaerobic environments.

Prior to initiation of the feasibility study, screening analyses, as previously described for the first case history, were performed on representative soil and ground water samples collected from the site. Ethylene glycol concentration was determined by direct aqueous injection into a Hewlett-Packard 5880 gas chromatograph (Hewlett-Packard Company, Palo Alto, CA) equipped with a 30-meter DB-5 fused silica capillary column (Supelco, Inc., Bellefonte, PA) and a flame ionization detector (FID). The limit of detection for the method was 50 ppm in water.

Screening analyses indicated that the ground water environment contained a viable microbial population; i.e., the environment did not appear toxic to microbial growth. Aerobic heterotrophic bacterial population densities ranged from 10^2 to 10^6 colony forming units (CFU) per milliliter (geometric mean = 1.2×10^4 CFU/ml, n = 4). Bacterial population densities of soil samples collected within the spill area varied from 10^2 to 10^6 CFU/g oven-dry soil (geometric mean = 2.2×10^4 CFU/g oven-dry soil, n = 8).

Screening analysis results also indicated that both pH adjustment and inorganic nitrogen and phosphorus nutrient additions would be necessary for biological treatment of ethylene glycol at the site. The pH of the 13 samples analyzed was 4.5 ± 0.49 ($\bar{x} \pm s$).

The biodegradation study was performed using the electrolytic respirometer. Using a composite ground water sample from the site, the electrolytic respirometer vessels were prepared as described in Table 4. Ethylene glycol biodegradation data for respirometer vessel 1 is presented in Figure 5. Loss of ethylene glycol was not observed in the abiotic control (vessel 4). The theoretical oxygen demand (ThOD) for mineralization of ethylene glycol was calculated from the following relationship:

$$2\ (CH_2OH)_2 \quad + \quad 5\ O_2 \rightarrow 4\ CO_2 \quad + \quad 6\ H_2O$$

The ThOD is 1.29 mg O_2 per mg of ethylene glycol following complete oxidation. With an initial concentration of 1440 ± 132 mg/liter ethylene glycol ($\bar{x} \pm s$, n = 20) 1860 mg O_2 would be required for complete oxidation. Ultimate BOD was determined using curve fitting techniques previously described for the first case history (Shammas, 1983).

Using the following relationship, it was determined that 94 percent of the theoretical oxygen demand for ethylene glycol biodegradation was met:

$$\frac{BOD\mu}{ThOD} \times 100$$

Thus, the results indicate that ethylene glycol was completely oxidized to carbon dioxide and water without the accumulation of incomplete oxidation products. With an ultimate BOD (BODµ) of 1700 ppm, an estimated minimum of 170 ppm NH_3-N and 17 ppm PO_4-P would be required in the ground water to prevent nitrogen and phosphorus from limiting microbial growth during biological treatment (Mitchell, 1974).

TABLE 4. TREATMENTS FOR ELECTROLYTIC RESPIROMETER BIODEGRADATION STUDY.

VESSEL NUMBER	TREATMENT
	NATURAL MICROBIAL FLORA
1	GROUND WATER + BASAL SALTS
	TOXICITY/INHIBITION CONTROL
2	GROUND WATER + BASAL SALTS + GLUCOSE
3	BASAL SALTS + GLUCOSE + MICROBIAL INOCULUM
	ABIOTIC CONTROL
4	GROUND WATER + BASAL SALTS + HgCl + KCN + NaN_3

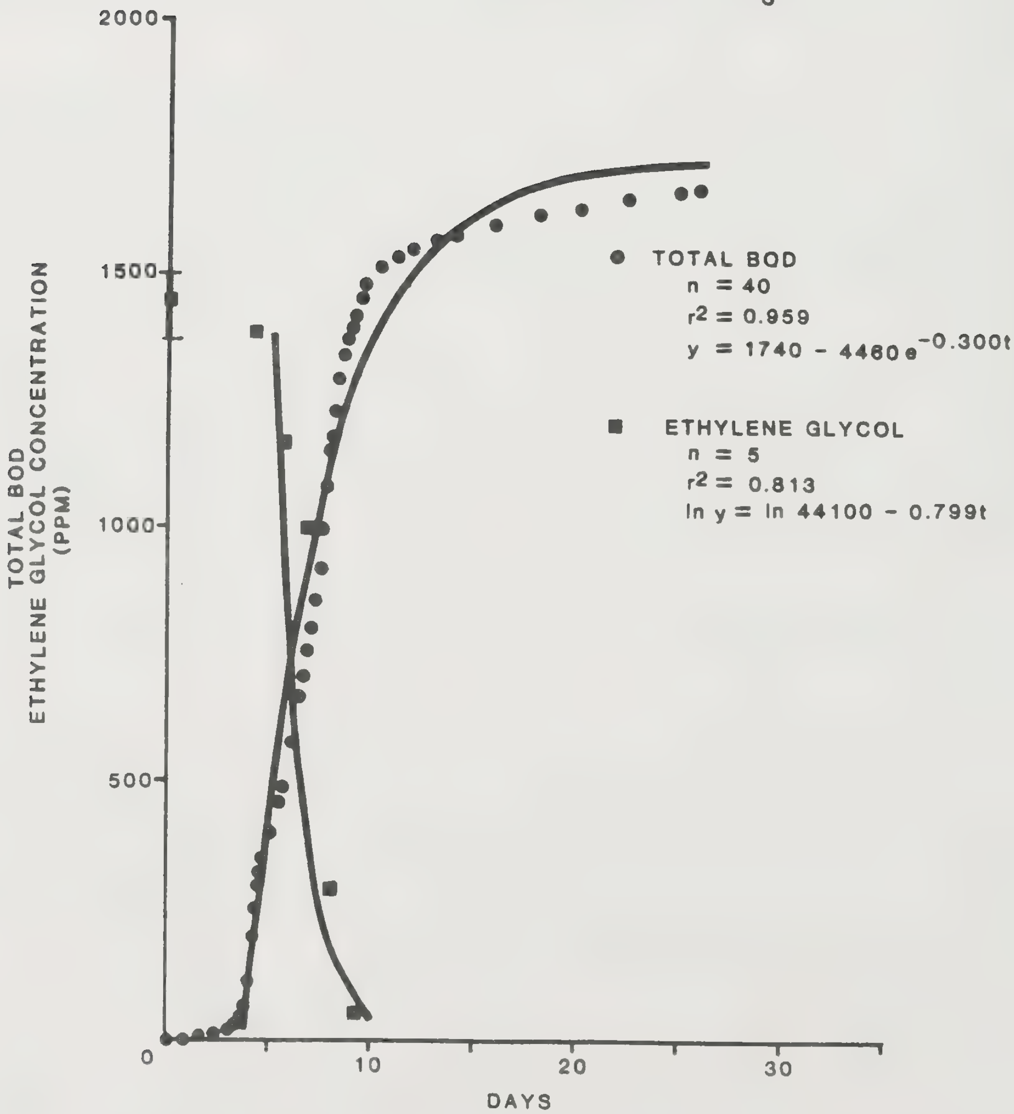

Figure 5. Biodegradation of ethylene glycol in composite ground water sample (vessel 1).

An exponential decay curve was used to quantify the removal rate of ethylene glycol by the natural ground water microbial flora in vessel 1 (Larson, 1980). Holding other variables constant, the rate of decrease was assumed to be a function of ethylene glycol concentration, i.e.

$$\frac{dC}{dt} = -kC$$

where,

C = the concentration of ethylene glycol remaining (ppm)
t = time (days)
k = the rate constant (day^{-1})

The curve generated was fit to the following first-order equation:

$$C = C_o e^{-kt}$$

where,

C_o = ethylene glycol concentration at time zero (ppm).

The first-order rate constant, k, was determined by linear regression using least squares, and the first-order equation was converted to

$$\ln C = \ln C_o - kt$$

The lack of a significant lag period in both oxygen uptake and ethylene glycol biodegradation by the natural microbial flora in vessel 1 indicated the presence of adapted microbes that could biodegrade ethylene glycol. That finding was significant because it indicated that *in situ* biodegradation of ethylene glycol was already occurring and that the management approach should be to increase the natural biodegradation rate.

The ground water environment appeared to be slightly stimulatory to microbial growth, as evidenced by the slightly greater rate of oxygen uptake in the composite ground water sample compared to the glucose-basal salts control (Figure 6). At the termination of the study, initial oxygen uptake data in the toxicity/inhibition control (respirometer vessels 2 and 3) were compared. On a semi-log plot, a comparison was made of the slopes of the lines-of-best-fit through the linear portion of the natural log transformed oxygen uptake data. In the linear portion of the semi-log plot, the rate of oxygen uptake in the glucose-containing composite ground water sample was 1.2 times greater than in the glucose-basal salts control. Thus, evidence for an environment toxic or inhibitory to microbial growth was not found.

Evaluation of feasibility study results indicated that biodegradation techniques were a viable option for reducing ethylene glycol concentration in the ground water environment.

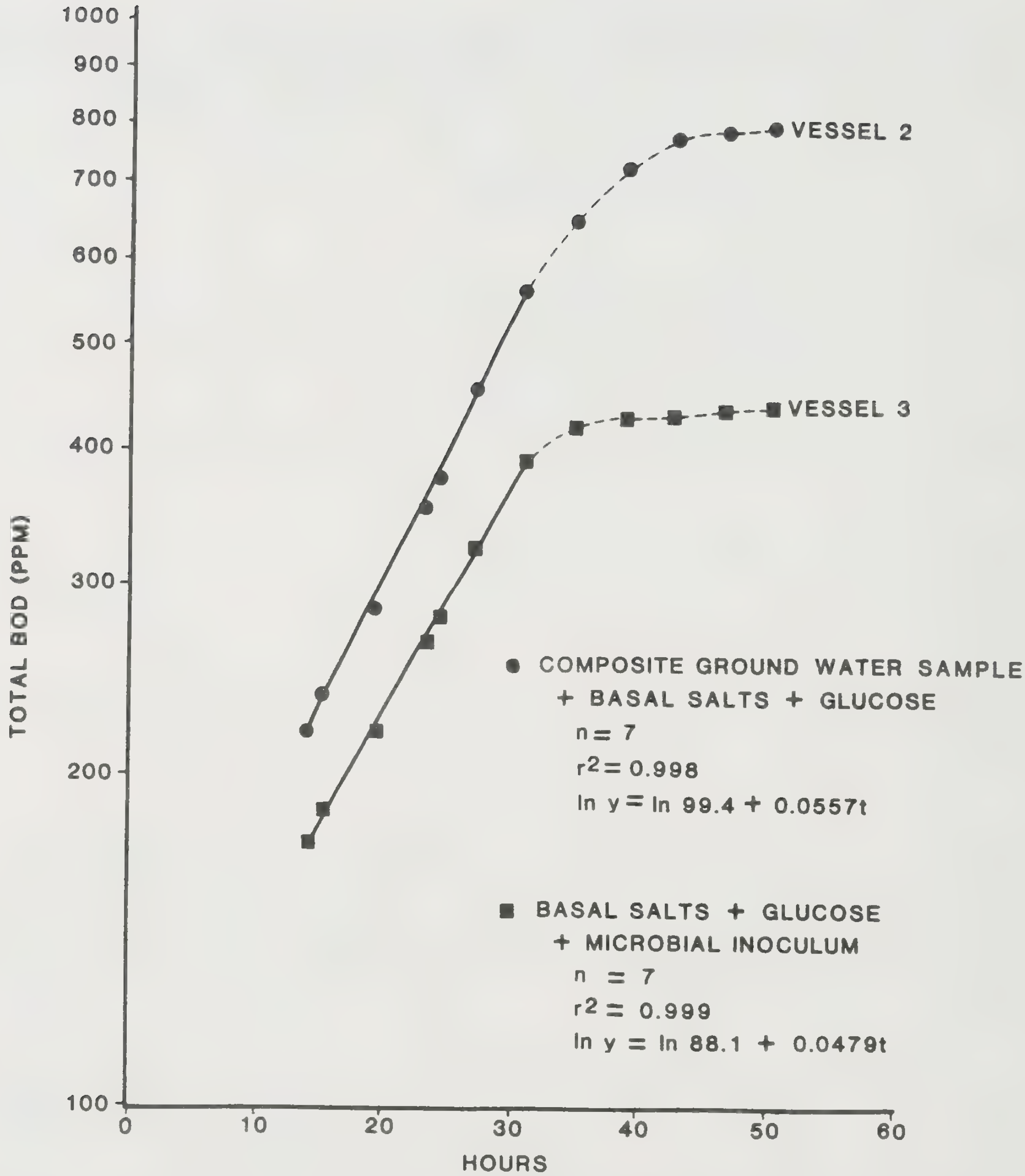

Figure 6. Oxygen uptake data for the composite ground water sample containing glucose and for a glucose control.

Field Implementation

The biological treatment program at the site was divided into a 14-day operational phase, a three-month monitoring phase, and a nine-month maintenance program. The operational phase was primarily designed to provide maximum recovery, treatment, and enhanced bacterial growth in the ground water both within the spill area and within the contaminant plume (Figure 7). Initial efforts during that phase also addressed the highly contaminated soil below the storage lagoon. The monitoring program was designed to assess the ethylene glycol degradation rate in the ground water following nitrogen and phosphorus nutrient addition, pH adjustment, and enhanced

bacterial growth. The maintenance program was designed to provide an environment suitable for the continued biodegradation of any residual ethylene glycol remaining in the ground water environment.

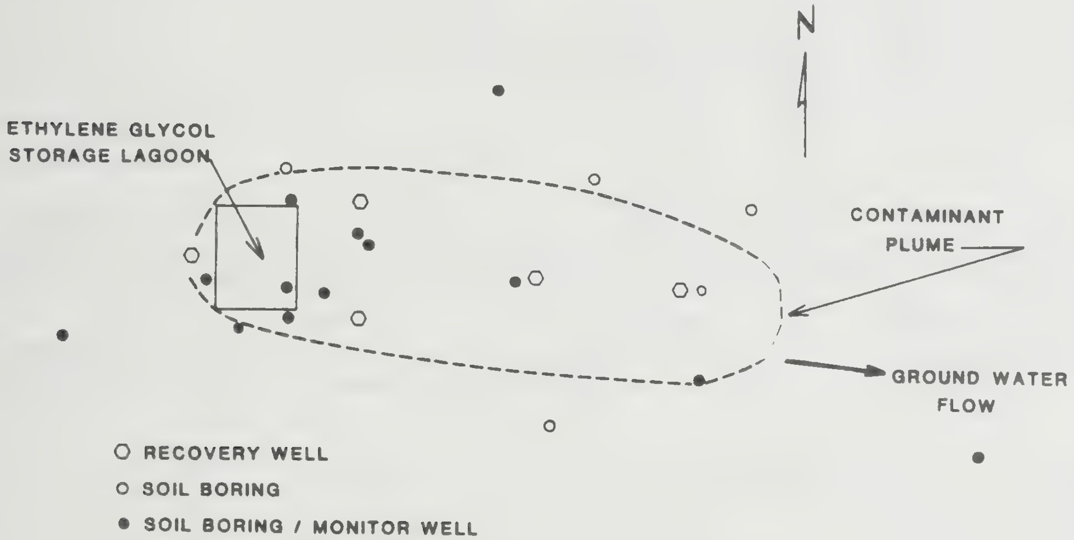

Figure 7. Schematic of ethylene glycol storage lagoon and contaminant ground water plume (surface view).

Ethylene glycol contamination at the site was divided into two areas. The first area was the unsaturated zone between the surface and the water table where ethylene glycol had been retained through capillary action. The highest contamination level detected in that zone was 4,900 ppm ethylene glycol. Surface contamination was also indicated following analysis of shallow samples (0 to 2 feet) collected adjacent to the lagoon.

The second area of contamination was the ground water. Ground water samples within the spill area had ethylene glycol concentrations as high as 2,100 ppm. Monitoring wells were installed to provide sampling points, and subsequent analyses indicated significant ground water contamination. A downgradient contaminant plume was identified east of the lagoon and was estimated to be 180 feet long by 45 feet wide.

A two-phased technical approach was implemented to deal with both soil and ground water contamination. Using injection and recovery wells, initial efforts addressed the highly contaminated soils underlying the storage lagoon. The second phase concentrated on ground water cleanup and was implemented to prevent further migration of contaminated ground water and to treat any contamination that would be released during treatment of the unsaturated zone.

Use of the underground recovery and treatment system for aquifer restoration has been previously described (Flathman, et al., 1983; Ohneck and Gardner, 1982; Quince and Gardner, 1982a, 1982b). For this project, the injection system was used to adjust ground water pH as well as provide the inorganic nitrogen and phosphorus necessary to support microbial growth. The recovery system withdrew contaminated ground water for above ground

treatment in an activated sludge treatment system (Figure 8). Effluent from the treatment system was then reinjected into the subsurface environment, creating a closed-loop system.

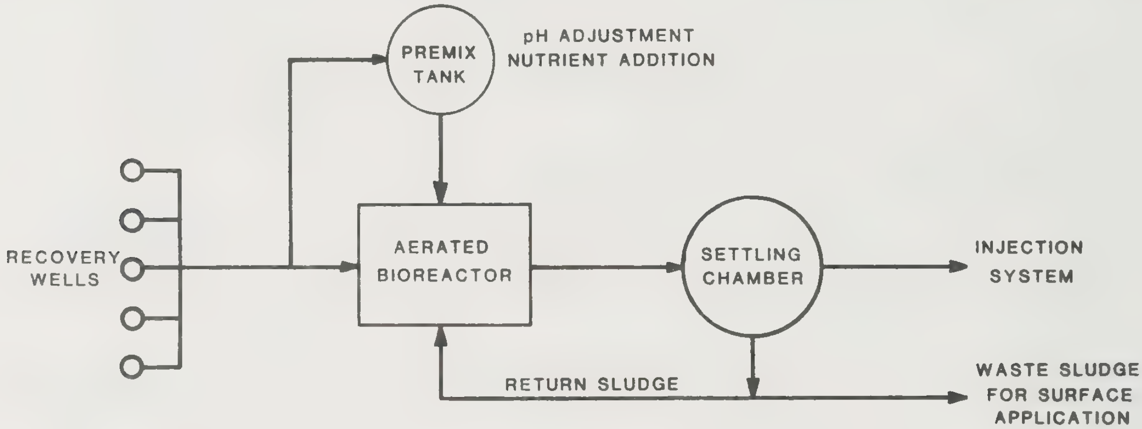

Figure 8. Flow diagram for the activated sludge treatment system.

The recovery system design was based on site investigations conducted by Naval Air Engineering Center and O.H. Materials Co. personnel. Based on the information obtained, five recovery wells were installed to recover contaminated ground water (Figure 7). Three wells located near the lagoon provided zones of attractions for inoculated water injected in that area. Two recovery wells were positioned east of the lagoon to recover contaminated water from the contaminant plume and aid in the distribution of the inoculated water from the plume injection system.

Following pH adjustment and nutrient addition, effluent from the biological treatment system was incorporated into a three-phase injection system. The lagoon injection system was employed to flush contaminated soil and thereby transmit contaminated water to the three recovery wells located in the vicinity of the lagoon. The individual injection points were positioned with a five-foot spacing and were placed to a depth of 15 feet. The wells were connected to a main distribution header, and valves were provided to adjust the flow at each point.

The plume injection system was similar to the lagoon system in both construction and operation. The individual plume injection points, however, were positioned with a 10-foot spacing. The primary functions of the plume injection system were to enhance bacterial growth through pH adjustment and nutrient addition and to create a gradient from the fringe of the plume toward the two recovery wells located at the center of the contaminant plume. The third injection phase was implemented through surface applications. Surface application was primarily used in the lagoon area to flush the unsaturated zone and enhance bacterial growth in the contaminated soil.

The activated sludge biological treatment system was designed to reduce ethylene glycol using the indigenous microbial flora and provide a source of adapted microorganisms for the three phase injection system (Figure 8). The biofeasibility study had demonstrated that the natural microbial flora

were adapted to degrading ethylene glycol and that the management approach for the project should be to increase the biodegradation rate using microbes indigenous to the ground water environment.

Nitrogen and phosphorus nutrient additions and pH adjustments were made to the recovered ground water through the use of a premix tank to the bioreactor. From the bioreactor, the treated ground water was pumped into a settling chamber. A portion of the settled sludge was recycled into the bioreactor with the remainder used, as needed, in the three-phase injection system.

Throughout the operational phase, treatment system and recovery well samples were analyzed for aerobic heterotrophic bacteria, pH, dissolved oxygen, inorganic nitrogen and phosphorus concentrations, and ethylene glycol. Based on the results of those analyses, environmental parameters were modified to maintain an effective rate of treatment. During the monitoring phase, those same parameters were quantified on a monthly basis from recovery well samples.

In those initial phases of treatment, ethylene glycol concentrations in two plume recovery wells had reduced from 690 and 420 ppm to below limits of detection (LOD = 50 ppm) within 26 days of treatment. These represent greater than 92 and 88 percent reductions in ethylene glycol concentrations, respectively. With the exception of one monitoring phase data point (day 40), ethylene glycol concentration remained below detection limits. As shown in Figure 9, ground water pH was maintained within an optimum range for bacterial growth (i.e., pH 6 to 7). Bacterial population density was returning to background levels following a high of 10^8 bacteria per milliliter of contaminated ground water.

In the two downgradient recovery wells adjacent to the storage lagoon, ground water concentration of ethylene glycol was reduced by more than 85 and 92 percent, respectively, within the first 26 days of treatment (Figure 10). Initial concentrations were 3,400 and 1,100 ppm, respectively. In the one upgradient recovery well adjacent to the lagoon, ethylene glycol concentration in the ground water had increased from 100 ppm on day 0 to 880 ppm by day 13. From that peak on day 13, monitoring data had shown a continued decrease in the ethylene glycol concentration. That increase in ethylene glycol concentration reflected the project's aggressive operational phase, where the injection system had flushed pockets of contamination from the unsaturated zone.

The maintenance program, which was manned by Naval Air Engineering Center personnel, focused on the removal of those remaining pockets of contamination, particularly in the lagoon area. As part of that program, both lime and diammonium phosphate were applied to the soil surface in the lgaoon and contaminant plume areas. Lime increased the pH of the soil/ground water environment to within a range more favorable to microbial growth. Diammonium phosphate, a readily available source of nitrogen and phosphorus, supported the growth of an increased microbial population.

By the completion of the project, ethylene glycol was reduced to below the limits of detection (LOD = 50 ppm) in all production wells at the site.

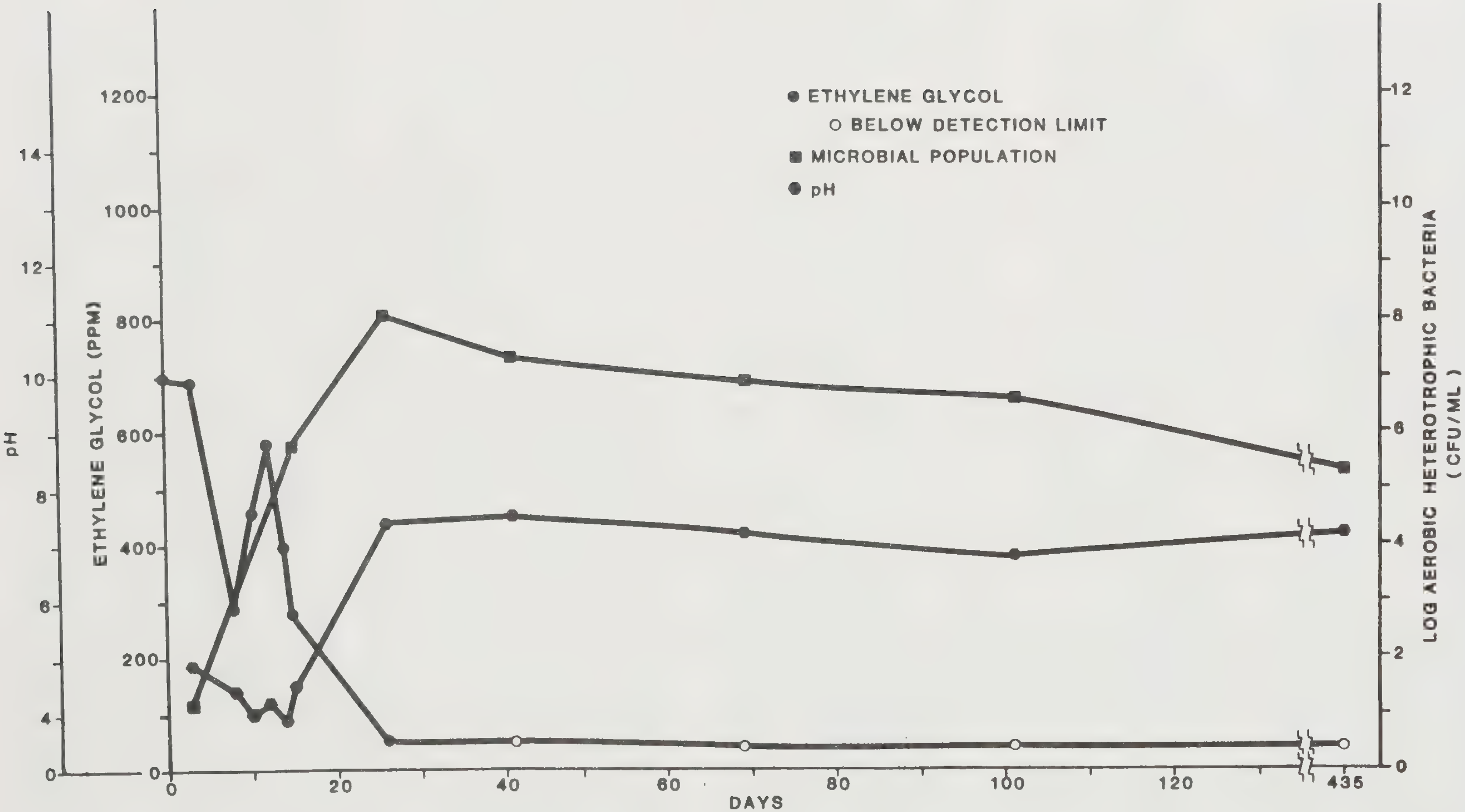

Figure 9. Ethylene glycol concentration, bacterial population density, and pH as a function of time for a contaminant plume production well.

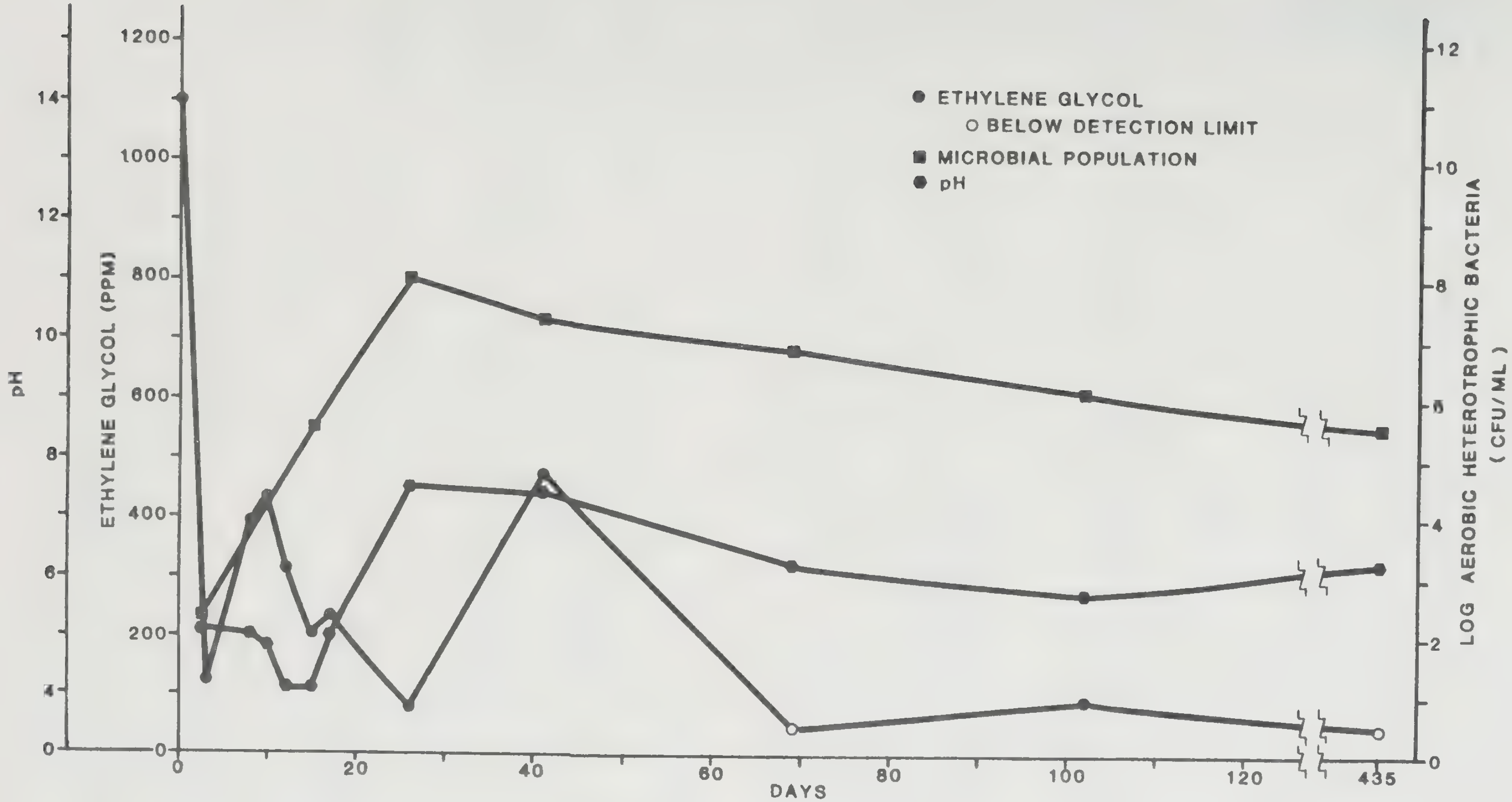

Figure 10. Ethylene glycol concentration, bacterial population density, and pH as a function to time for a downgradient spill area production well.

Discussion and Conclusion

The two case histories presented demonstrate the application of biological techniques for environmental restoration of areas contaminated with hazardous organic materials. As described in the first case history, a sizeable cost savings was achieved and future liability was substantially reduced by successfully decontaminating the soil at the site. Biodegradation offered substantial cost advantages over excavation, transportation, and disposal.

Biological techniques, as described in the second case history, effectively removed ethylene glycol from the ground water environment at a relatively rapid rate. The flexibility of the injection/recovery system in maintaining an environment conducive to biodegradation while flushing ethylene glycol from the ground water environment was a key factor in the removal of scattered pockets of contamination.

Biodegradation as a method for spill cleanup and environmental restoration is a promising technology. Land treatment techniques have been gaining acceptance as an economical and environmentally sound means of destruction for many types of industrial wastes (Flathman, et al., 1983; Loehr, et al., 1979; Parr, et al., 1983; Vernick and Walker, 1981). With regard to cleanup of contaminated soil and ground water, physical removal, by convention, has been a common method for remediation. However, biological techniques are now gaining increased acceptance as a practical, cost-effective alternative for environmental restoration.

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REMOVAL OF TRICHLOROETHYLENE AND RELATED INDUSTRIAL SOLVENTS BY AIR STRIPPING

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The treatment plant described in this paper was built to remove volatile organic chemicals from extracted groundwater. When initially conceived, little had been published on removal of volatile organic chemicals by air stripping. A pilot plant was built in 1981 to test a range of operating variables. Testing was conducted from 1982 through early 1983. As a result of the pilot testing, modifications were made and operation of the plant was optimized. The plant began full-scale operation in June 1983. Testing has proven the plant capable of reducing total concentrations of volatile organic chemicals in influent from more than 10,000 parts per billion (ppb) to less than the limits of detection (<1 ppb) for these chemicals. The plant is capable of treating up to 1.7 million gallons per day (mgd).

CHARACTERISTICS OF PLANT INFLUENT

Influent to the pilot plant was different than influent to the full-scale plant because different groundwater extraction wells were used. In addition, influent concentrations decreased over time as the pilot plant operated. Influent concentrations during pilot plant testing and full-scale operation are shown in Table 1. Influent concentrations have been summarized as total volatile organic chemicals (VOC) which represents the sum of the individual volatile organic chemicals shown in Table 1.

PILOT PLANT

The pilot treatment system included a 0.5-mgd extraction well, a small flow equalizing surge basin, a 1.0-mgd capacity air stripping treatment plant consisting of four towers, three recharge wells, and a 1.2-acre infiltration pond. Because of the need for information on

TABLE 1

AVERAGE INFLUENT CONCENTRATIONS, PPB

Compound	During Pilot Testing	During Full-Scale Operation
Trichloroethylene	3,000	760
Freon 113	2,000	320
Tetrachloroethylene	500	140
T-1,2-Dichloroethylene	80	36
1,1,1-Trichloroethylene	20	ND
1,1-Dichloroethylene	60	11

performance of large-scale air stripping facilities in removing volatile organic chemicals, considerable flexibility was designed into the system. All four towers could be operated in series or flow could be split through two parallel sets of towers operated in series.

Each tower is 22 feet high, 5 feet in diameter, and constructed of four sections of reinforced fiberglass. A typical tower is shown on Figure 1. Each tower is filled with approximately 200 ft^3 of packing. The packing used is Norton No. 3 Hy-Pak aluminum alloy packing. Hy-Pak was chosen because of its high void fraction (97 percent free space). Metal packing was chosen over plastic to avoid the possibility of trace amounts of organic compounds leaching from the packing material into the treatment system. The packing in each tower consists of two 5-foot deep sections. Each section is supported by a stainless steel support grating.

Air was supplied to the pilot plant towers by two blower fans. Each fan was rated to supply up to 10,000 cubic feet per minute (cfm) of air through a pressure drop of 2 inches of water. In the pilot plant, air from each blower was split evenly between two towers. Air flow could be reduced to 150 cfm per tower by dampers located in the splitter box.

PILOT PLANT OPERATION

Extended operation of the pilot plant began on March 10, 1982. Operation from March through September 1982 was used as a shakedown period. The plant was operated on a generally variable schedule with periodic routine maintenance and preparation for various test procedures. Daily operating conditions and treatment plant performance are shown in Figure 2. Over the period March through September, the ability of the plant to remove volatile organic chemicals was proven. Influent total VOCs ranged from 10,000 to 2,600 ppb. With the exception of measurements taken shortly after start-up of the plant, the total concentration of effluent VOCs were consistently below detectable limits.

During initial operation of the plant, a number of physical and operational changes were made. An injection system to add carbon dioxide to plant effluent was added. During the air stripping process, pH of the water rises. Addition of carbon dioxide lowers the pH and thus reduces the possibility of carbonate precipitation. The utility of activated carbon for removing VOCs from air discharged by the plant was also tested during initial operation. Trailer mounted carbon units were used for the testing and mist eliminators were added to the towers.

FIGURE 1
AIR STRIPPING TOWER

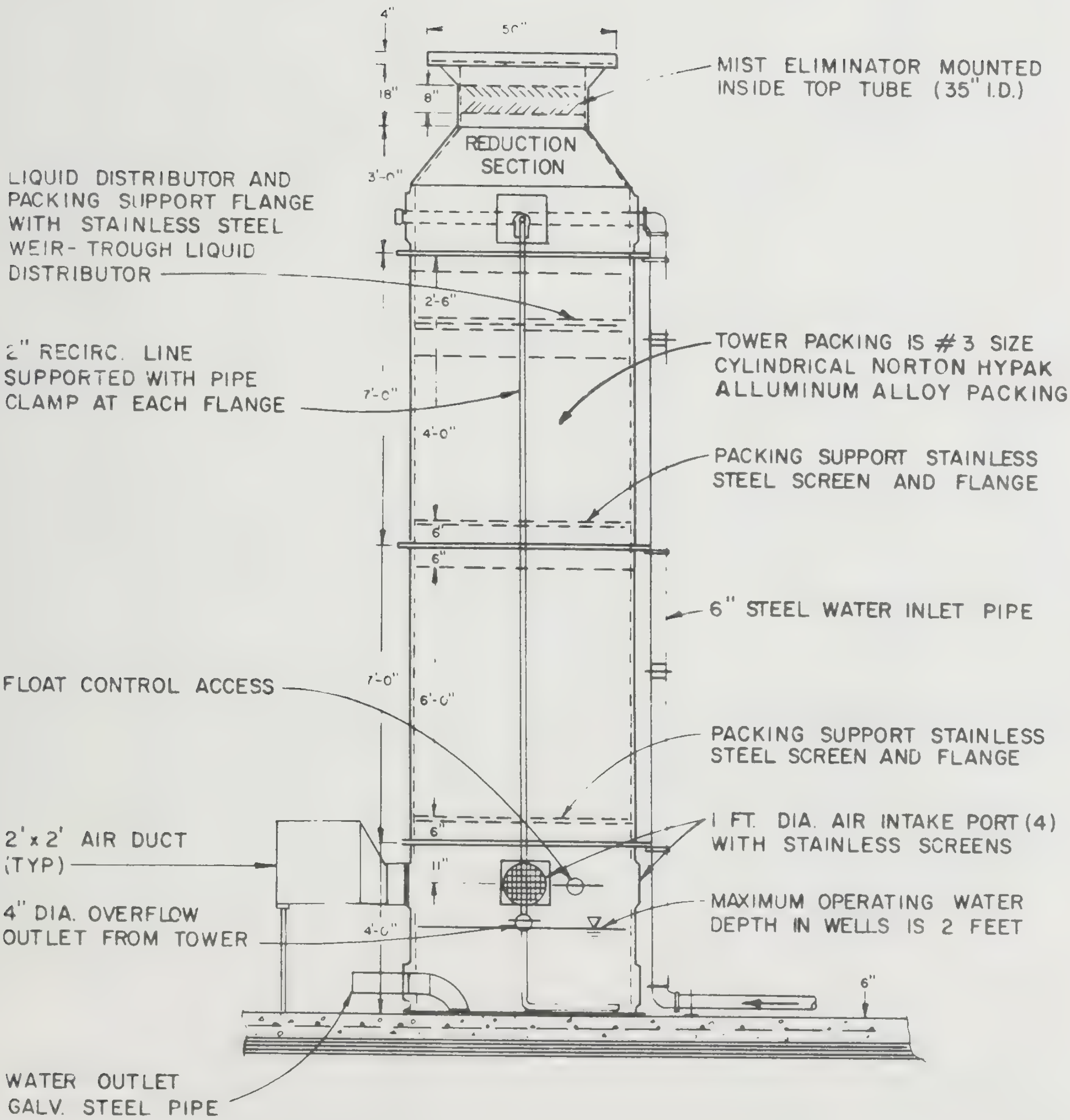
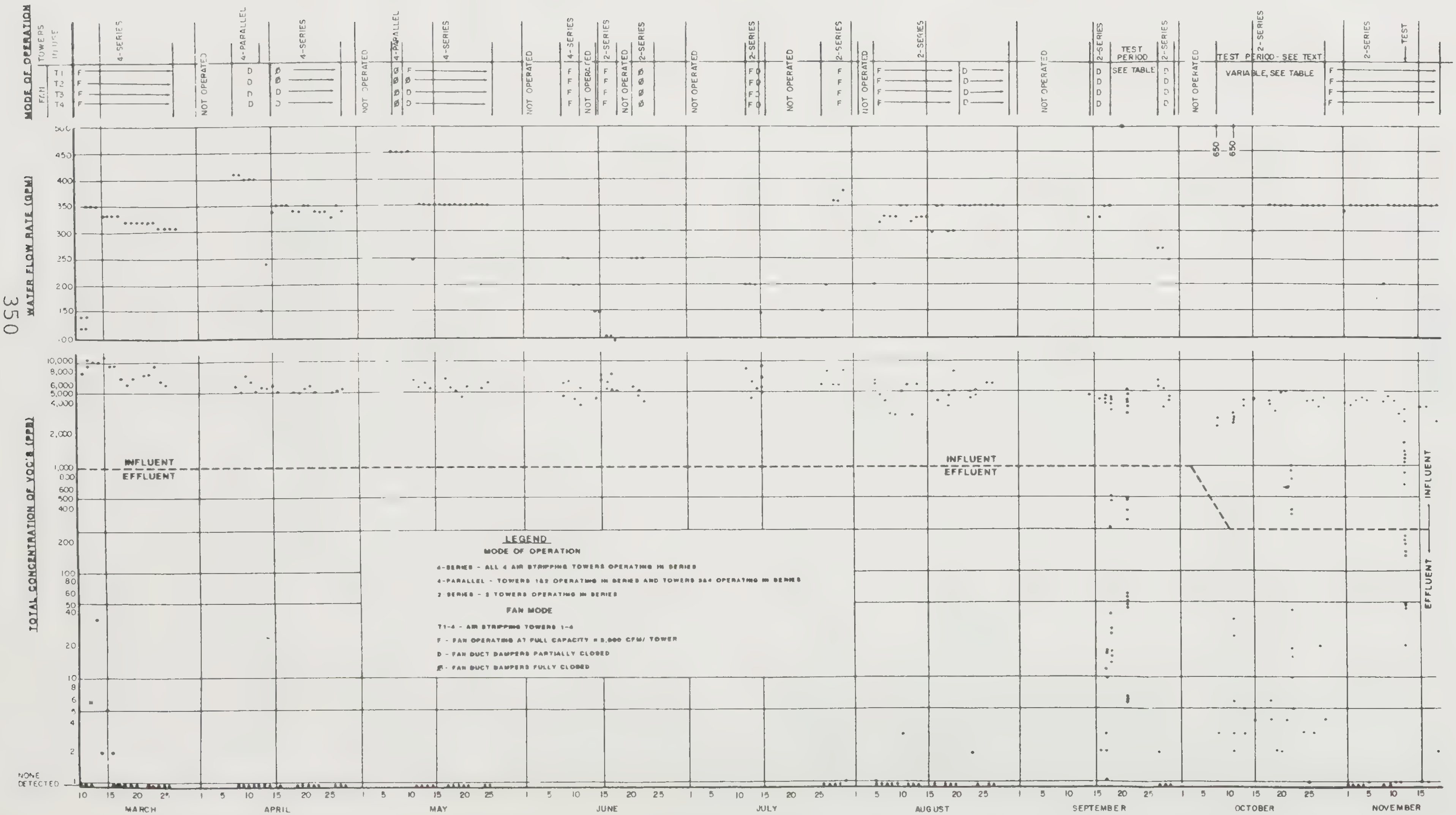


FIGURE 2
FOLSOM BLVD PILOT TREATMENT PLANT
SUMMARY OF OPERATIONS AND DATA



It was apparent during initial operation of the plant that adequate removal of VOCs could be obtained operating two parallel series of two towers each. This mode of operation was selected for tests to determine efficiency of removal of VOCs over a range of air to water ratios and to determine the hydraulic capacity of the plant. Tests were also conducted to determine if the air stripping process would remove 1,2-dichloroethane. This compound is not normally found in treatment plant effluent.

Water flow rates ranging from 350 to 650 gallons per minute (gpm) and air flow rates ranging from 375 to 4,350 cfm were tested. Results of the tests are summarized on Figures 3 and 4. As would be expected based on Henry's constants, air stripping is not as effective for removing 1,2-dichloroethane as for the other solvents.

FULL-SCALE PLANT

Modifications were made to the pilot treatment system during early 1983. The full-scale plant utilizes the same air stripping towers and site as the pilot plant. New extraction and recharge fields were developed and a prefabricated 20,000-gallon surge tank was added. Major modifications to the air ducting system were made which recirculate the air discharged from the first tower in each series to the second tower in each series. The original blowers were modified with addition of intake dampers and positive control dampers and supply control dampers, and supply 3,500 cfm to each series of towers. At the plant's design capacity of 1.7 mgd the gas:liquid molar ratio is about 0.034. Computerized controls also were added to the plant enabling operation with minimal manual adjustment.

Activated carbon beds were added to the plant to remove chemicals from air from the stripping towers. The activated carbon system consists of two beds which provide for continuous operation while alternate beds are regenerated. The carbon is regenerated with steam and a distillation process enables recovery of nearly pure, recyclable solvent. The carbon beds are monitored continuously and the carbon regeneration process is activated automatically. Condensate from the carbon regeneration system is returned to the influent stream.

THE TRANSFER UNIT CONCEPT

The performance of the air stripping process can be examined by utilizing the concept of the transfer unit. The number of transfer units required to achieve a stated reduction in liquid concentration of solute characterizes the difficulty of stripping that compound from

FIGURE 3
EFFECTIVENESS OF TREATMENT FOR TRICHLOROETHYLENE WITH TWO TOWERS VERSUS THE MOLAR GAS TO LIQUID RATIO

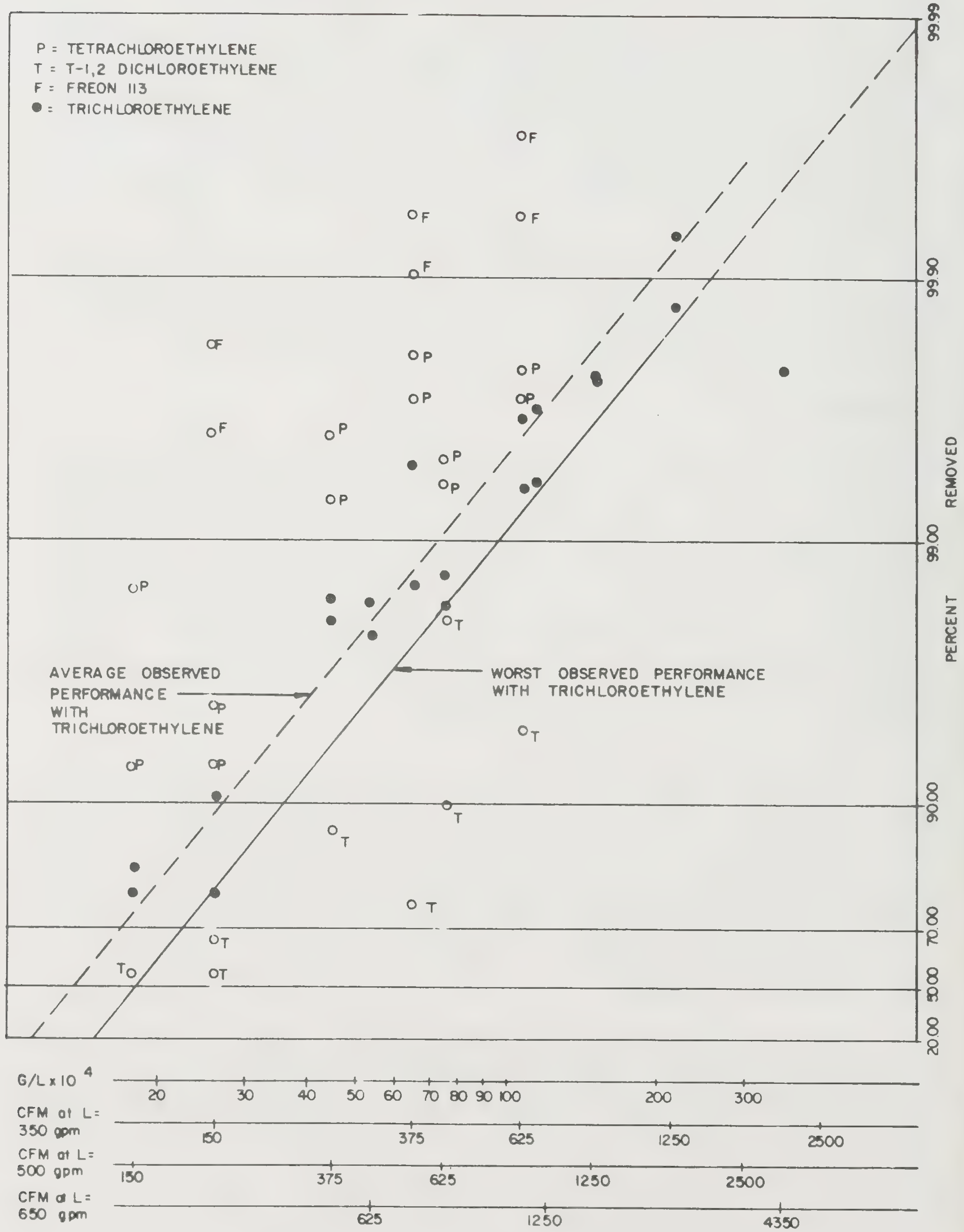
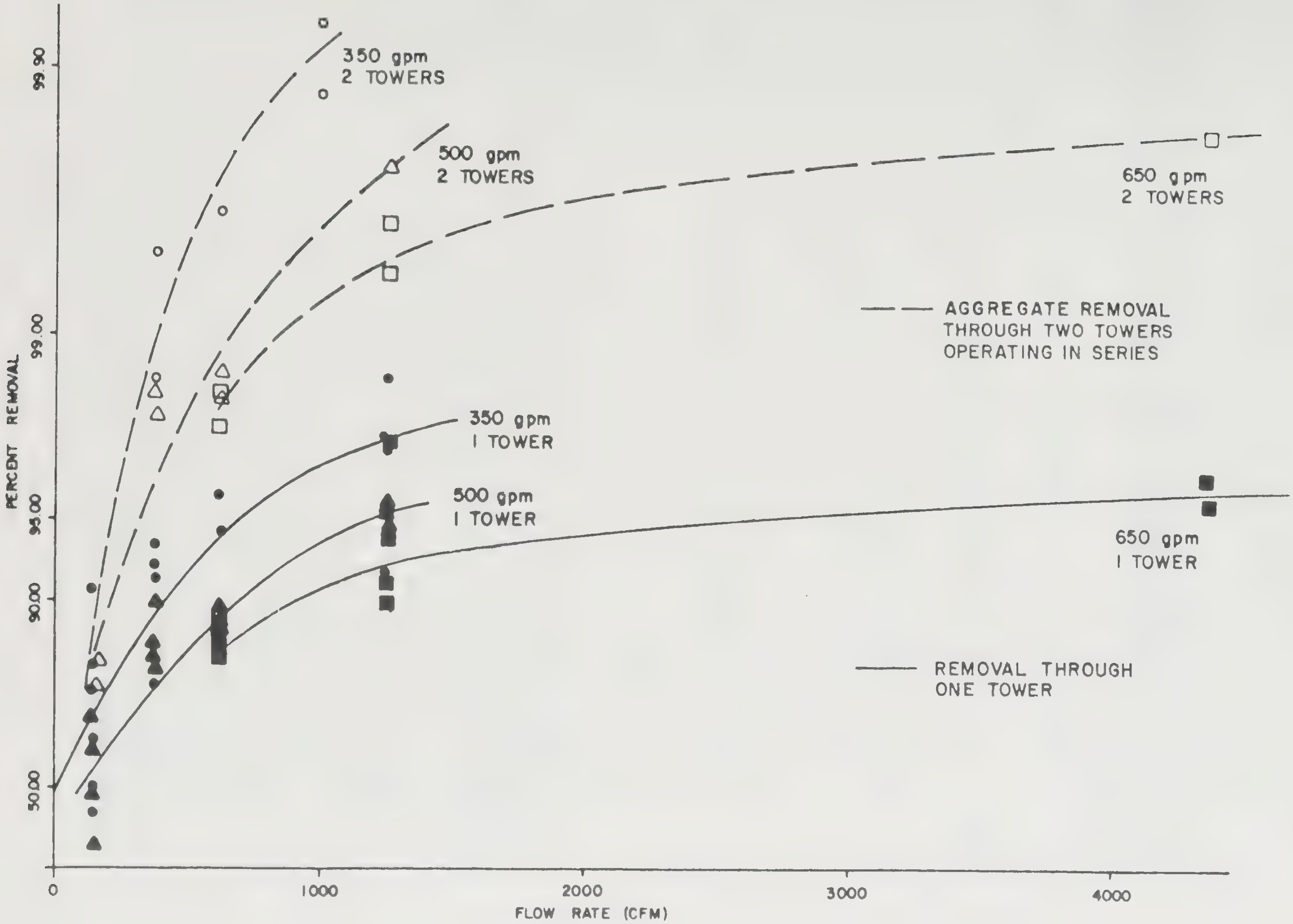


FIGURE 4
EFFECTIVENESS OF TRICHLOROETHYLENE REMOVAL
IN 1 AND 2 TOWERS AT DIFFERENT
WATER AND AIR FLOW RATES



solution. The number of transfer units will differ for each compound considered. For dilute solutions, the number of transfer units (NTU) in a stripping process is modeled for each compound with the following equation:

$$NTU = \left(\frac{R}{R-1}\right) \ln \left[\frac{Cin/Cout\ (R-1) + 1}{R}\right] \tag{1}$$

where: R = Stripping Factor $= \left(\frac{H_A}{P_t}\right) \cdot \left(\frac{G'}{L'}\right)$

H_A = Henry's Constant, atm

G' = Molar gas flow rate (moles/min$\cdot$ft^2)

L' = Molar liquid flow rate (moles/min$\cdot$ft^2)

Cin = Influent concentration, moles/I

Cout = Effluent concentration, moles/I

P_t = System pressure in atmosphere

Thus, a process in which a particular chemical is reduced in concentration by a stated proportion is succinctly represented by a single index which incorporates operating conditions together with physical and chemical properties. Once the number of transfer units is known for a specific tower its performance can be predicted under various alternative operating conditions.

The number of transfer units in a packed tower for a particular compound is related to the total depth of packing by the following equation:

$$Z = (HTU)(NTU) \tag{2}$$

where:

Z = Depth of packing (feet)

HTU = Height of a transfer unit (feet)

From percentage removals measured in this experiment, the number of transfer units and heights of transfer units for trichloroethylene, tetrachloroethylene, and Freon 113 have been calculated.

For calculation of the number and height of transfer units, Henry's Constants for trichloroethylene and tetrachloroethylene were estimated at 72°F from the following empirical relationship:

$$\log H_A = H^o/RT + K \qquad (3)$$

where:

H_A = Henry's Constant, atm

R = Universal gas constant (cal/mole°K)

T = Temperature (°K)

H^o = Enthalpy change due to dissolution of Component A in water (cal/mole°K)

K = Constant

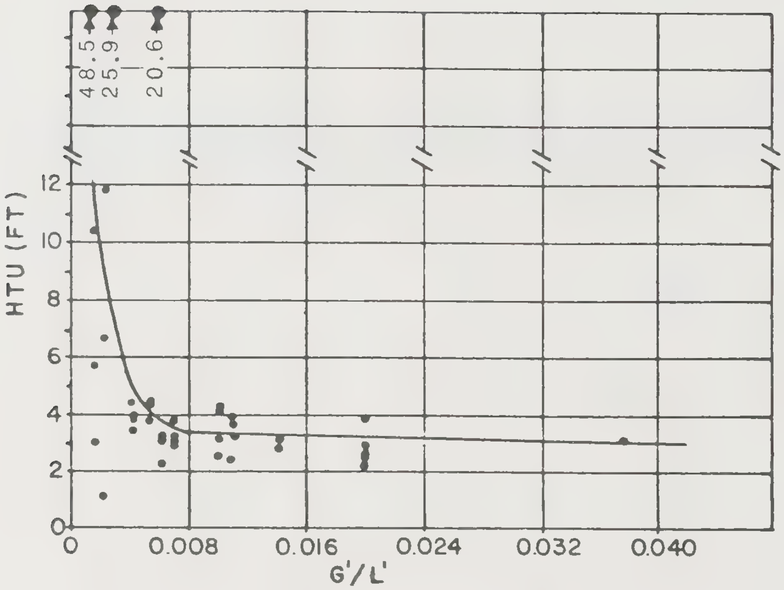
Values of constants in Equation (3) reported in the literature used to adjust estimates of Henry's Constants for trichloroethylene and tetrachloroethylene from 20°C (68°F) to 22°C (72°F) are:

Compound	H^o	K
Trichloroethylene	3.41	8.59
Tetrachloroethylene	4.29	10.38

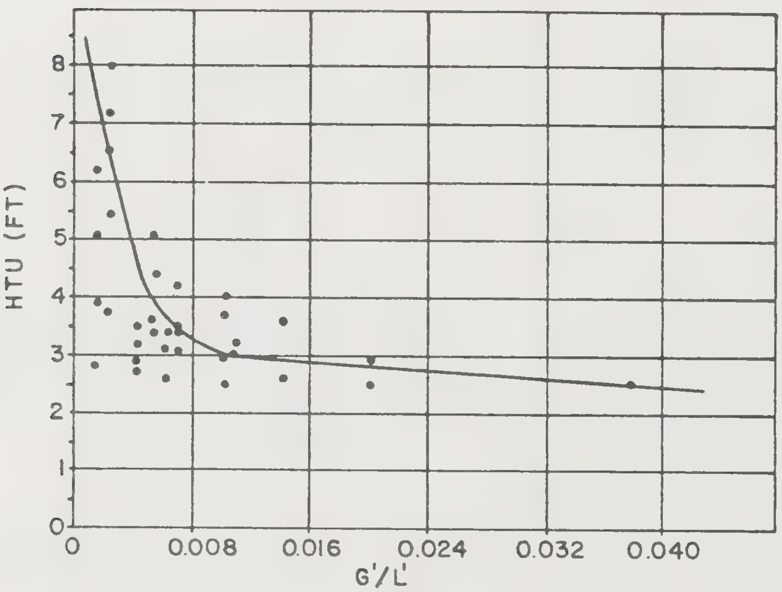
A value of Henry's Constant for Freon 113 was calculated based on the reported solubility and vapor pressure of that compound at 25°C[2]. No adjustment for temperature of the Henry's Constant of Freon 113 was made. Because of the few removal efficiencies obtained in this experiment for trans-1,2-dichloroethylene, characteristic heights of transfer units for this compound were not made.

The calculated values of heights of transfer units for these components have been plotted as a function of the molar air and water ratio (G'/L') in Figure 5a, b, and c. Calculated values of HTU in excess of the scales included in Figure 5 have been shown with arrows, and include only high HTU values for trichloroethylene. Curves have been drawn by inspection through the data points. Curves through the data presented in Figures 5a, b, and c can be seen to rapidly approach a minimum value of the height of a transfer unit after which increases in the air to water ratio have little effect. In the flat portions of these curves, large increases in values of G'/L' produce little decrease in the height of a transfer unit. The flat portions of these curves correspond to operation at excessive air flow rates. The minimum values of the HTU for the compounds are:

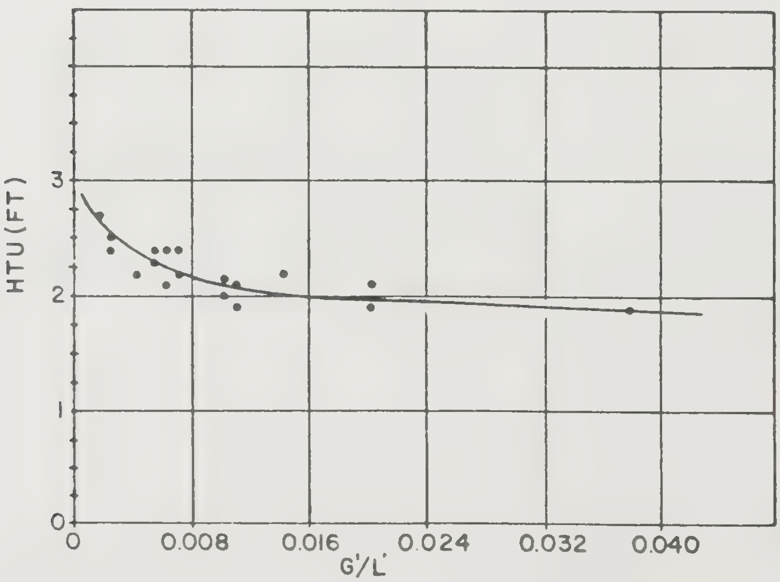
FIGURE 5



A) TRICHLOROETHYLENE HTU AT VARIOUS AIR TO WATER RATIOS



B) TETRACHLOROETHYLEN HTU AT VARIOUS AIR TO WATER RATIOS



C) FREON 113 HTU AT VARIOUS AIR TO WATER RATIOS

Compound	Estimated Minimum Height of a Transfer Unit (feet)
Freon 113	1.9
Tetrachloroethylene	2.5
Trichloroethylene	3.0

Using values of the minimum heights of transfer units, the treatment efficiency of the treatment plant can be estimated for each compound at higher liquid loading rates. The maximum number of transfer units in each tower calculated by use of Equation (2) is:

Compound	Depth of Packing (ft)	Minimum Height of Transfer Unit (ft)	Number of Transfer Units In Each Tower
Freon 113	10	1.9	5.3
Tetrachloroethane	10	2.5	4.0
Trichloroethylene	10	3.0	3.3

Based on the number of transfer units achievable in each tower, expected effluent concentrations of each compound from each tower can be estimated at higher liquid loading rates using Equation (1). Estimates of effluent concentrations from each of four towers operated in series over a range of hydraulic loading rates from 500 to 700 gpm are presented for each compound in Table 2. Estimates of effluent concentrations in Table 2 are for air flow rates of 4,000 cfm and assumed inflow concentrations of each compound which go beyond the typical influent values observed to give adverse case estimates. Typical influent higher concentrations observed for each compound and the concentration used for the estimation are:

Compound	Typical Values (ppb)	Adverse Case Values Selected for Estimation (ppb)	Worst Case Values Selected for Estimation (ppb)
Freon 113	2,000	3,000	6,000
Tetrachloroethylene	500	700	900
Trichloroethylene	3,000	4,000	5,000

TABLE 2

CALCULATED CONCENTRATIONS OF FREON 113,
TETRACHLOROETHYLENE, AND TRICHLOROETHYLENE
IN EFFLUENT FROM EACH OF FOUR AIR STRIPPING TOWERS
OPERATED IN SERIES
(AIR FLOW RATE = 4,000 cfm)

	Water Flow (gpm)	Influent Concentration (ppb)	Calculated Concentration Leaving Each Tower (ppb)			
			Tower 1	Tower 2	Tower 3	Tower 4
Freon 113	500	2,000	10	<1	<1	<1
	600	2,000	10	<1	<1	<1
	700	2,000	10	<1	<1	<1
Tetrachloroethylene	500	500	10	<1	<1	<1
	600	500	10	<1	<1	<1
	700	500	10	<1	<1	<1
Trichloroethylene	500	2,000	78	3	<1	<1
	600	2,000	79	3	<1	<1
	700	2,000	80	3	<1	<1

As shown on Table 2, concentrations of Freon 113 and tetrachloroethylene are projected to be less than 1 ppb after the first tower, even at peak hydraulic loading conditions. Low concentrations of trichloroethylene would be expected after treatment through two towers under peak hydraulic loading conditions, even with the adverse case influent concentrations. Trichloroethylene would be reduced to less than 1 ppb after treatment through the third tower.

Analogous calculations can be made using Equation (1) with other air and liquid flow rates and influent concentrations. Interpretations can also be made of the benefit of increasing the depth of packing in each tower.

FULL-SCALE OPERATION

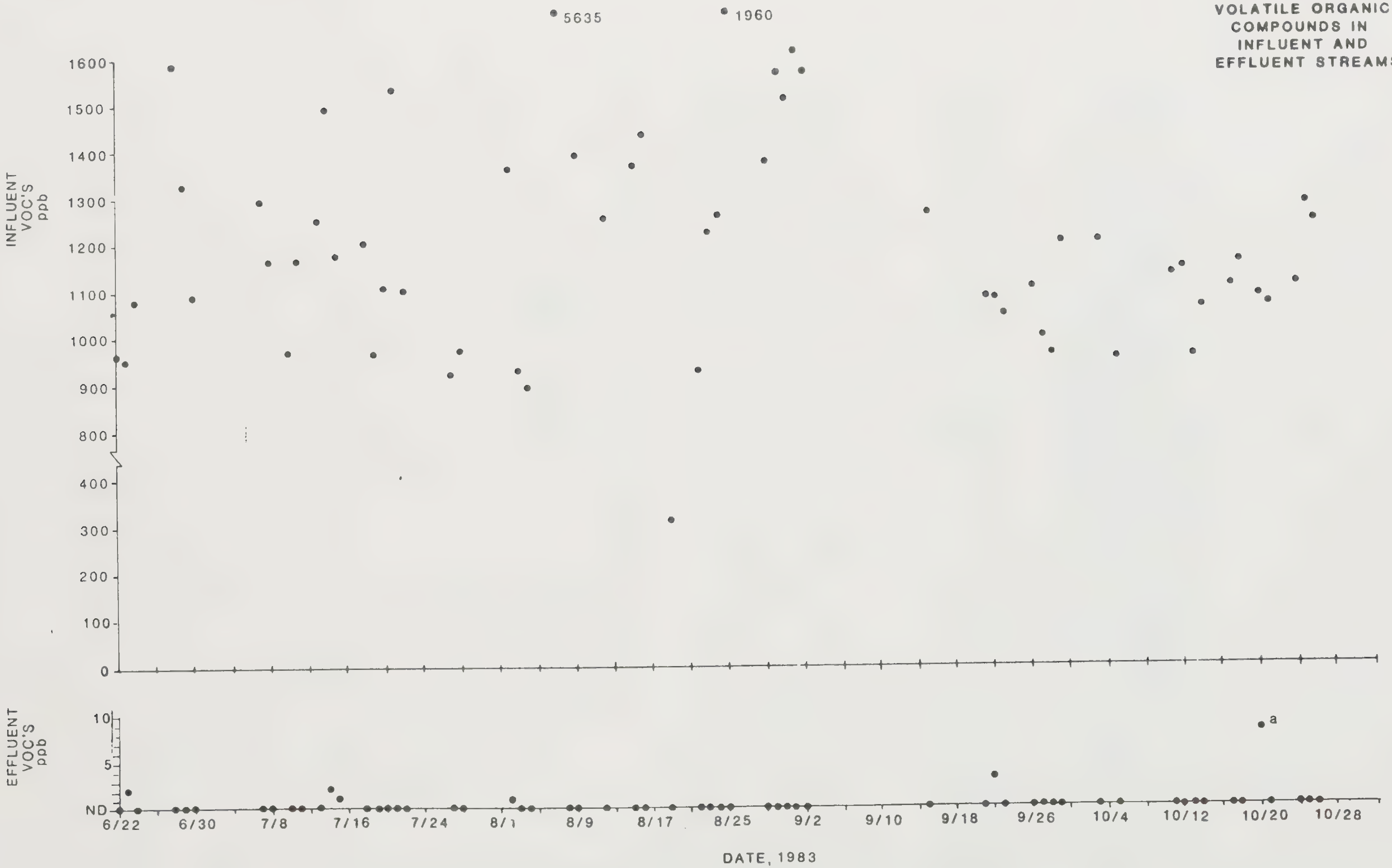
The full-scale plant began operating on June 22, 1983. Over the period June 22 through December 31, 1983, the plant treated about 210 million gallons of groundwater. Typical operating parameters for the plant are presented in Table 3. Influent and effluent total VOCs are shown on Figure 6. As seen by these data, the plant has consistently reduced influent VOCs to less than the limits of detection, a 99.9 percent removal efficiency.

TABLE 3
TYPICAL OPERATING PARAMETERS

Parameter	Typical Range
Influent VOC's, ppb	900 - 1,600
Liquid flow, gpm	500 - 1,300
Gas flow, cfm	7,000
CO_2 rate, cfh	100
Influent pH	6.0 - 7.0
Effluent VOC's, ppb	ND*
Effluent pH	6.0 - 7.0
Gas : Liquid Ratio	0.044**

*Not detectable
**At 900 gpm

FIGURE 6
CONCENTRATIONS OF
VOLATILE ORGANIC
COMPOUNDS IN
INFLUENT AND
EFFLUENT STREAMS



[a] SAMPLE SUSPECTED TO HAVE BEEN CONTAMINATED

REFERENCES

1. Kavanaugh, M. C. and R. R. Trussell; "Air-Stripping as a Treatment Process," Journal of AWWA, 5:72(12); December 1980

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TCA AND TCE CLEANUP IN THE SANTA CLARA VALLEY

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INTRODUCTION

Recent widely publicized incidents involving organic contamination of drinking water in the Santa Clara Valley have received considerable interest from concerned private citizens, the high-tech electronics industry, and the Federal Environmental Protection Agency. Unlike highly visible traditional environmental problems such as air or surface water contamination, groundwater exposure to toxic organics is not readily apparent nor easy to detect. Yet, subsurface water contamination poses a serious threat to the nation's drinking water supplies. The EPA is taking dramatic steps to address threats to the country's drinking water supplies. In particular, the 1984 RCRA reauthorization specifically includes provisions designed to control and mitigate groundwater contamination arising from storage of motor fuels and solvents.

Environmental engineers from Exceltech, Inc., together with hydrogeologists from Weiss Associates, conducted an extensive TCE and TCA cleanup program in the Santa Clara Valley. This report describes the fundamental approach and subsequent techniques employed to treat contaminated water pumped to the surface. Since the cleanup activities involved two separate sites, the technical discussion presented below represents a composite summary of both remediation programs. In both instances the water treatment techniques were essentially the same; namely, air strippers coupled with carbon bed adsorbers. However, the extraction system design (i.e., quantity and location of water wells) varied between projects depending on site-specific hydrogeologic patterns.

This paper presents a composite overview of two groundwater cleanup programs, with a special emphasis on key process engineering consideration regarding water extraction and treatment. Beginning with excavation of contamination sources, the discussion will proceed in chronological order to address:

1) specification and design of distributed groundwater extraction systems,

2) design, construction and operation of a water treatment process for removing chlorinated hydrocarbons at low concentration, and

3) permit requirements confronted at each step from initial extraction pipe installation to final treated water discharge to the storm sewer.

EXCAVATION

The first step of any groundwater remediation program involves the identification and subsequent removal of the contamination source together with soil directly exposed to the contaminant. Similar to many groundwater contamination problems, the leak source was found to be tanks and associated piping used for temporary storage of spent solvent. As indicated in Tables 1 and 2, tanks, piping and soil were excavated and disposed as hazardous material in a Class I hazardous waste landfill.

The extent of said contamination was delineated using on-site analytical services. Soil tests were performed using a dual-column Varian 3700 gas chromatograph equipped with electron capture detectors (ECD) for rapid and accurate analysis of chlorinated hydrocarbons. On-site soil testing provided several distinct advantages over more common testing at an outside laboratory. First, the immediate availability of soil test results served to guide the excavation activities. Therefore, only soil

Table 1

REMEDIAL CLEANUP PROGRAM

Item	Resolution
o Tanks and Piping	-- Excavation
	-- Disposal
o Soil	-- Excavation
	-- Disposal
o Groundwater	-- Extraction
	-- Treatment

Table 2

EXCAVATION

- o Delineate Extent of Contamination
  - -- Limited Monitoring Well Soil and Water Testing
  - -- On-site Analytical Services
- o Remove Contaminated Materials
- o Transport and Dispose of Wastes
  - -- Permits
  - -- Waste Classification
- o Site Restoration

confirmed to be contaminated was transported to a landfill for disposal. Secondly, once contaminated soil was removed, the excavation could be immediately backfilled with pea gravel; Exceltech did not leave open, unsafe excavation pending return of laboratory test results. Aside from the obvious necessity to backfill the open excavation, site restoration also provided an excellent opportunity to incorporate specific construction features into the effected area. In particular, a six inch diameter extraction well, submersed in pea gravel fill, was installed in the open pit for subsequent extraction of contaminated ground water. The larger outer surface area of the permeable gravel backfill greatly increased the potential extraction rate from the soil directly exposed to high levels of chlorinated hydrocarbons. In addition, a concrete slab, constructed over the gravel back-fill, was predesigned and constructed to later support air stripper and carbon bed water treatment equipment.

EXTRACTION SYSTEM

Once short-term remediative activities encompassing excavation and disposal were completed, Exceltech process engineers began long-term cleanup tasks composed of groundwater extraction and surface water treatment. A variety of extraction techniques are available to accomplish control and removal of a subsurface contaminant plume:

O <u>Slurry Wall</u> -- consisting of a deep (10 to 30 feet) and and narrow (approximately 2 feet) impermeable material, a slurry wall traps contaminant plumes confined to a shallow depth. This approach is frequently used for petroleum leaks where the insoluble product lies confined to the groundwater surface.

- French Drain -- Of the same geometry, but substituting permeable gravel material for the concrete in a slurry wall, french drains trap contaminant plumes by exposing groundwater to a low resistance conduit where water is withdrawn for subsequent surface treatment.

- Distributed Extraction System -- In situations where the contaminant plume has dispersed over a wide area, slurry walls and french drains may not effectively capture and recover the contaminated groundwater. Here a distributed extraction system composed of multiple extraction wells are employed to remove affected groundwater.

Based on the hydrogeological site investigation performed by Weiss Associates, Exceltech installed a distributed-well extraction system to remove TCE and TCA contamination from the groundwater. Designed to contain the relatively large contaminant plume, the distributed extraction network consisted of multiple extraction wells interconnected by a subsurface trench linking each well to a common, centralized water treatment process.

As shown in Figure 1, the extraction system covered an area 300 feet long, including five separate wells. Despite the low contamination levels (less than 10ppm chlorinated hydrocarbons), local city hazardous material storage ordinances required that all piping comply with double containment restrictions; thus, the epoxy coated concrete trench provided required secondary containment for the primary water piping.

Extraction wells were designed to be self-contained, but actuated from a common control panel. As summarized in Table 3, each well included separate level and flow controls to protect sensitive

Figure 1

Distributed Extraction System

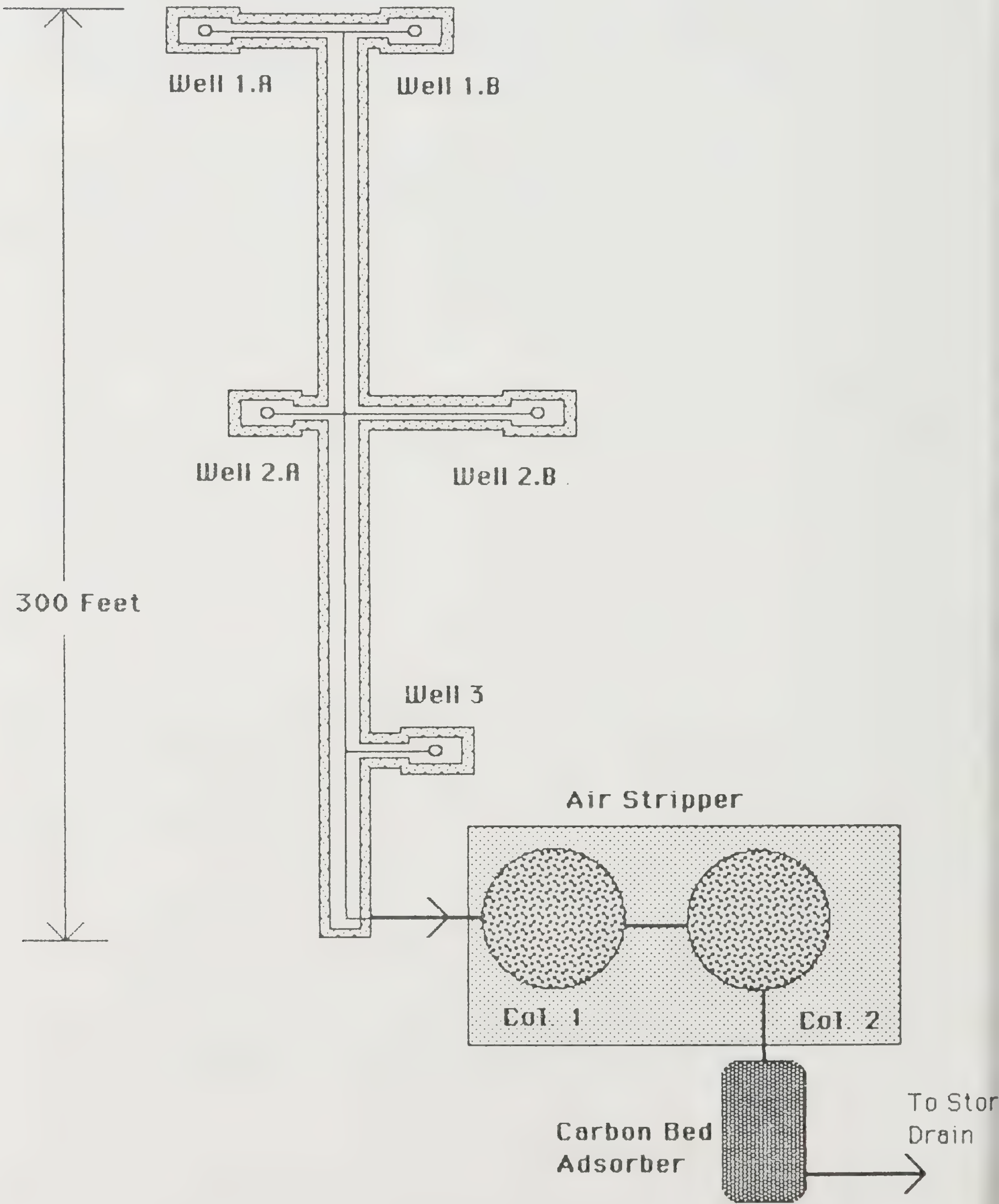

Table 3

GROUNDWATER EXTRACTION SYSTEM

- o Distributed Extraction Network
  - -- Horizonal and Vertical Coverage
  - -- Interconnected Piping
- o Self-Contained Extraction Wells
  - -- 4 in. Submersible Pumps
  - -- Remote Level and Flow Controls
- o Centralized Water Treatment System
  - -- Air Stripping
  - -- Carbon Adsorption

submersible pumps while automatic shut-off capability was maintained at the water treatment system control panel. Exceltech provided comprehensive turn-key service, from initial process and control design to final construction and operation.

WATER TREATMENT

Since total chlorinated organic levels in the groundwater (5 to 20ppm) exceeded effluent limits, water pretreatment was required to discharge water to either a storm drain or the local sewer treatment plant. As reviewed in Table 4, the water treatment system design depended on three primary factors:

1) flowrate,

2) inlet organic loading, and

3) discharge requirements. Each of these factors are discussed briefly below.

Water treatment flowrate was defined by the minimum groundwater extraction rate necessary to achieve capture of the subsurface contaminant plume. Increased extraction rate was further balanced against higher capital and operating costs associated with a larger water treatment system. Based on a rough economic analysis, a nominal extraction (and therefore treatment) rate of 40 to 75 GPM was established.

Inlet organic loading, while it varies from well to well, is entirely predetermined by the existing contamination levels. Chlorinated hydrocarbon levels, including both TCE and TCA, varied from 5 to 20ppm.

Table 4

WATER TREATMENT DESIGN PARAMETERS

- o Inlet Conditions
  - -- Flowrate : 40 to 75 GPM
  - -- Contaminant Levels : 5 to 20 ppm
    Chlorinated Hydrocarbons

- o Target Outlet Parameters
  - -- Destination : Surface Waters or Reuse
  - -- Contaminate Levels : 10 to100 ppb
    TCO

Discharge requirements represented the most complex design parameter. Two treatment discharge alternatives were available:

1) Publicly Owned Treatment Works (POTW) or sewer treatment facility.

2) Storm Drain entering local surface waters.

Although preliminary discussions with the local POTW indicated that treated water would be accepted at organic levels as high as 100ppb, subsequent policy changes restricted discharges to emergency, last resort circumstances only. Apparently, the POTW realized that accepting water effluents from several groundwater remediation programs, while extremely low in organic loading, would quickly surpass the hydraulic capability of the treatment facility.

With the POTW option eliminated, discharge to the storm drain remained as the only viable alternative. Surface water discharges fall under the jurisdiction of the Bay Area Regional Water Quality Control Board, which established 100ppb chlorinated organic effluent limit to be achieved by the best available control technology (BACT).

With the overall design parameters specified as a nominal flowrate of 40 to 70 GPM, inlet concentrations of up to 20,000ppb TCE/TCA, and outlet concentration of 100ppb, Exceltech process engineers evaluated available water treatment technologies based on technical performance, reliability and cost. Two treatment processes were selected: packed-column air strippers and carbon bed adsorbers. As summarized in Table 5, air stripping offered low cost with

Table 5

TREATMENT PROCESS SELECTION

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o Packed-Column Air Stripping

-- Low Cost (0.5 to 0.75 $/1,000 Gal.)

-- 98 Percent Removal Efficiency

o Activated Carbon Adsorption

-- Moderate Cost (1.0 to 2.0 $/1,000 Gal)

-- Extremely Low Effluent Levels

-- Reliable, Predictable Performance

o Air Stripper/ Carbon Bed Combination

typical removal efficiencies of 98 percent. Activated carbon beds, in contrast, represented moderately higher treatment costs, but extremely low effluent levels (less than 10ppb). Exceltech selected an air stripper/carbon bed combination where, in the first stage, an air stripper removes the bulk of the volatile organic compounds, while the second stage carbon bed reliably "polishes" the water discharge to effluent levels below 10ppb.

Volatile organic removal is achieved in an air stripper when air and water are contacted countercurrently in a packed column. Based on chemical equilibrium and diffusion phenomenon, organic compounds in the water are stripped by the air to be discharged into the atmosphere. A typical packing height of approximately 14 feet is required to achieve chlorinated organic removal of 98 percent. Although total column heights approaching 18 to 19 feet are common in practice, public visibility at this particular contamination site restricted total heights to a maximum of 12 feet. Consequently, a dual column configuration (7 feet of packing each) operated in series was employed to achieve required removal efficiencies. A schematic of the dual column air stripper design is presented in Figure 2.

Air stripper performance exceeded the baseline design criteria of 98 percent efficiency. As shown in Figure 3, at an inlet TCA concentration of 4000ppb, the intermediate and outlet TCA concentrations were 40 and 0.5ppb TCA (nondetectable), respectively. This represents a first and second column efficiency of over 99 percent each, or an overall removal efficiency exceeding 99.99 percent. The enhanced performance of the dual column system was attributed to two factors:

1) water was remixed and redistributed by the intermediate pump between the two columns, and

Figure 2

Dual Column Air Stripper

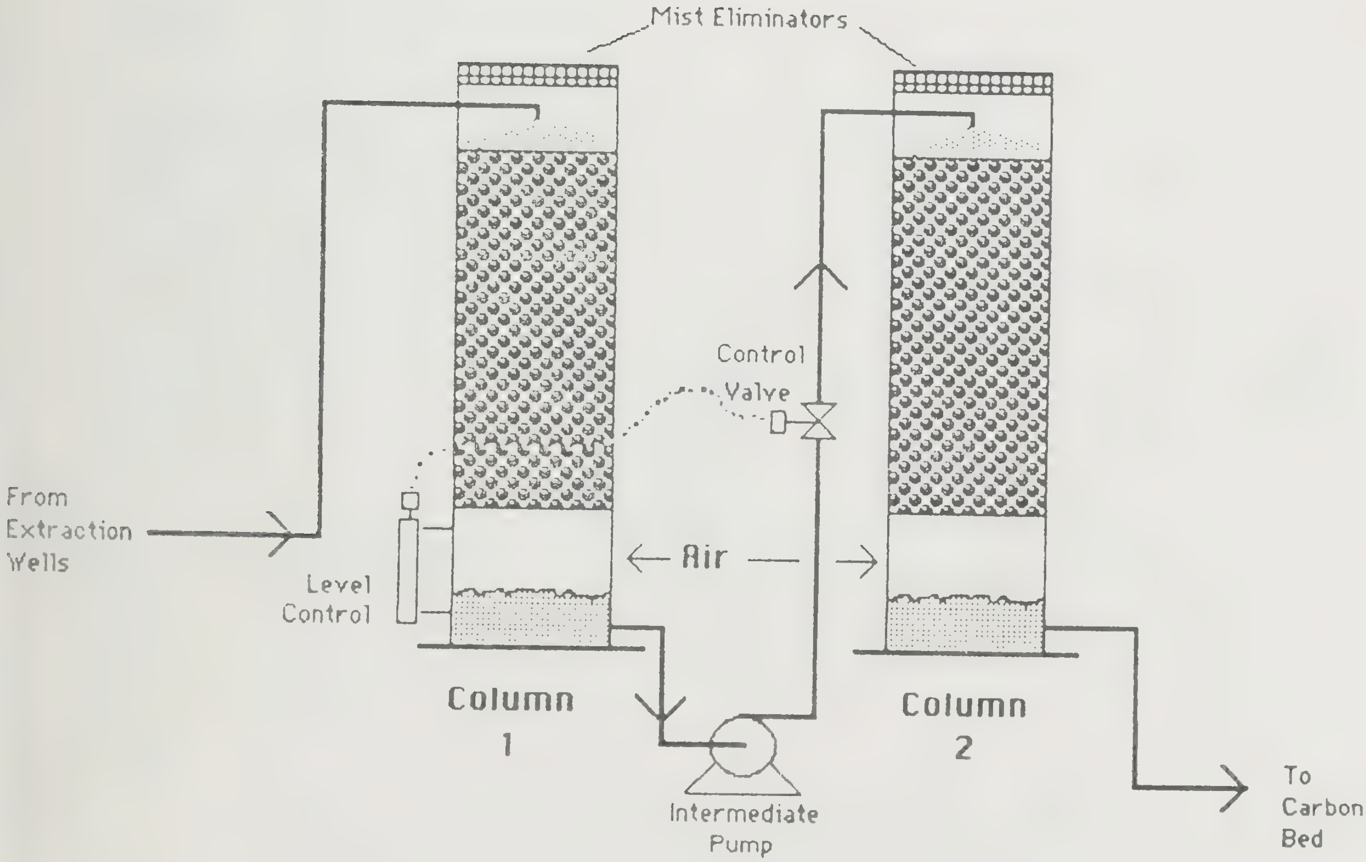
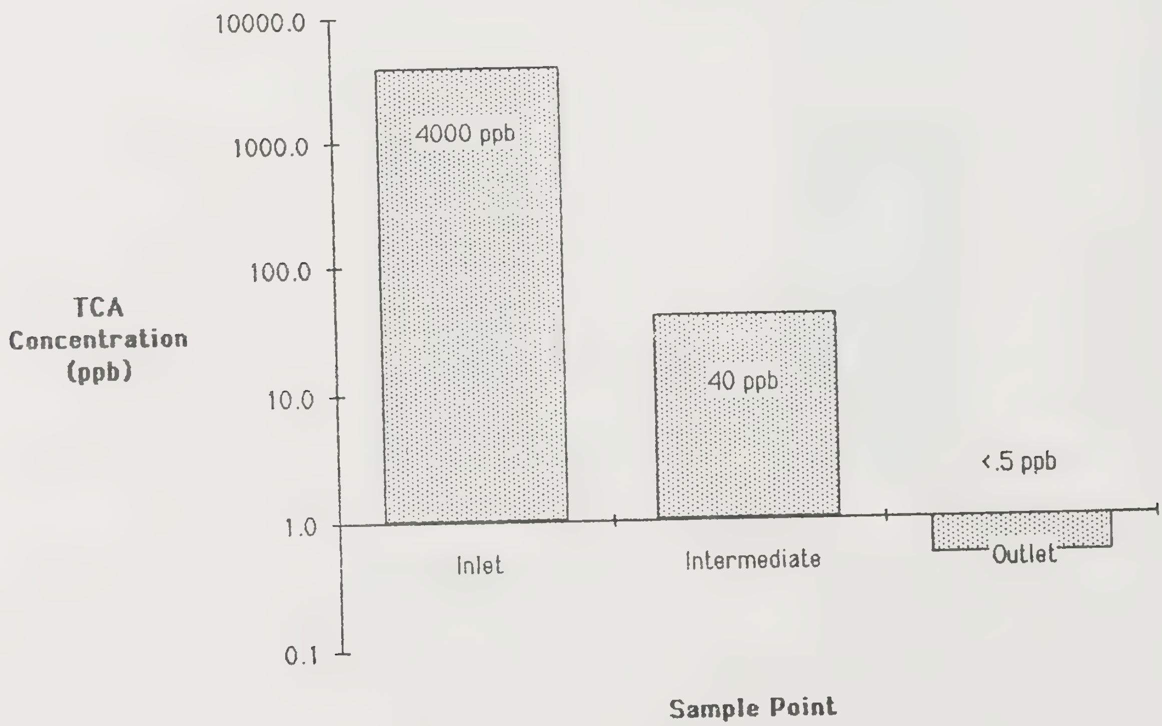


Figure 3 Air Stripper Performance



2) fresh air, injected into the second column, provided improved overall stripping performance.

Prior to installing the air stripper, an activated carbon bed adsorber was operated at the untreated inlet organic loading level of 6000 to 8000 ppb TCA. As predicted, extremely low effluent levels were obtained; TCA discharge concentrations were measured as nondetectable, or less than 0.5ppb. Please refer to Figure 4.

PERMITS

Discussing environmental remediation would not be complete without addressing the exhaustive permit requirements inevitably associated with a water treatment program. As reviewed in Table 6, permits are required from the initial groundwater monitoring well to the air and water discharge permits for the air stripper and carbon bed. Regulatory interface is required with the following government agencies:

- California Department of Health Services (DHS) -- Maintains overall cleanup responsibility under California Title 22 and federal RCRA hazardous work regulations. Excavation and waste disposal activities require specific permits from the DHS.

- Regional Water Quality Control Board -- Jurisdiction encompasses permits for monitoring wells and treated water discharges to surface waters. Together with DHS, establishes ultimate groundwater cleanup levels.

- Bay Area Air Quality Management District (BAAQMD) -- The BAAQMD restricts point sources organic discharges to a maximum 15 lbs/day. Prior to operation, the air stripper must be permitted by BAAQMD.

Figure 4 Carbon Bed Performance

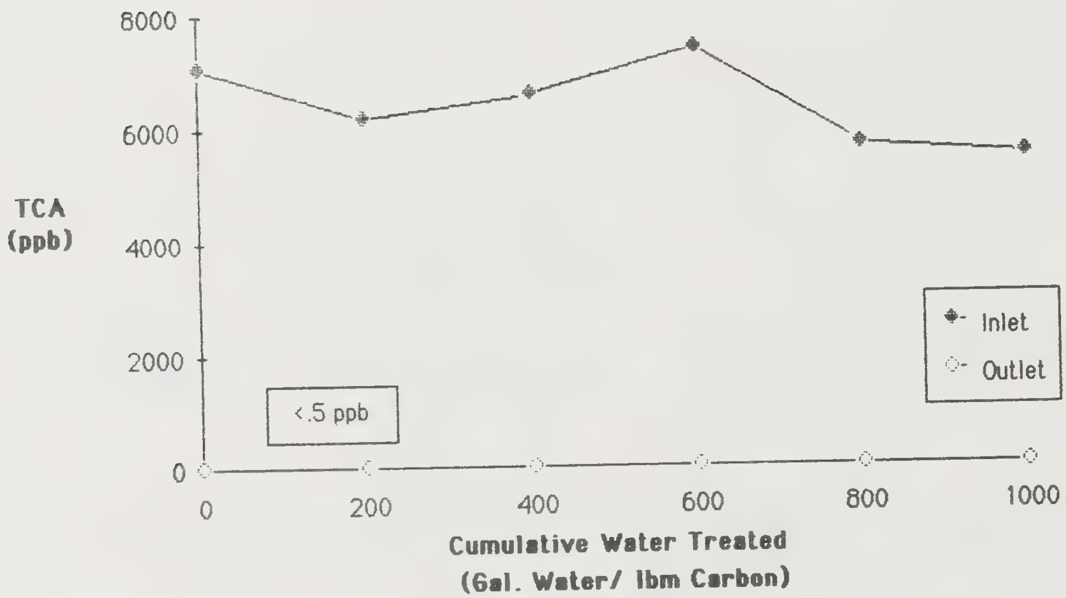


Table 6 : PERMITS

- o Excavation/ Monitoring Well Installation
  - -- Cal. Department of Health Services
  - -- Regional Water Quality Control District
  - -- Local Fire Department
- o Trench and Treatment System Construction
  - -- Local Fire/ Health Department
  - -- City Building Inspector
- o Water And Air Discharges
  - -- Regional Water Quality Control Board (NPDES Permit)
  - -- Waste Water Treatment Plant (POTW)
  - -- Bay Area Air Quality Management District

- O Local Fire Department -- Within the last couple of years, many local city and county governments have taken the initiative to establish hazardous material management plans (HMMP) regulating the storage and handling of hazardous materials. Local fire departments are often given the authority to enforce the regulations. Requirements for monitoring underground storage tanks and/or installation of secondary containment devices are usually a key element of the HMMP programs. Consequently, fire department permits are required for monitoring wells, piping systems (i.e., distributed extraction network), and operation of a water treatment process (to ensure double containment).

- O City Building Inspector -- All construction activities, including water treatment processes and associated piping, require a city building permit.

SUMMARY

Recent installation of underground tank monitoring wells has revealed considerable groundwater contamination from petroleum products as well as solvents. Nowhere is the impact of groundwater contamination more evident then in the Santa Clara Valley where the improper handling and storage of degreasing fluids has resulted in high exposure of groundwater supplies to chlorinated solvents. Exceltech Inc., together with Weiss Associates, has successfully performed two comprehensive programs involving TCE and TCA contamination.

The initial hydrogeologic study, conducted by Weiss Associates, established the extent of contamination and the general guidelines for a remediation program. Based on the large subsurface area effected, a distributed extraction technique, rather than slurry walls or french drains, was used to remove groundwater for sub-

sequent surface treatment.

Exceltech environmental and process engineers provided turn-key design and construction services from initial excavation of the contamination source to final operation of suitable water treatment systems. Please refer to Table 7. On-site analytical services immediately established the extent of soil contamination, thereby limiting the quantity and time required to remove affected soils. Groundwater extraction was accomplished employing multiple extraction wells interconnected by a common manifold to a centralized water treatment process.

Based on a technical and economic evaluation, a combined air stripper/carbon bed water treatment system was selected to achieve less than 100ppb effluent discharge limits. A dual column air stripper process exceeded overall design performance standards of 98 percent volatile organic removal by achieving over 99.99 percent efficiency. At inlet concentration of 4000ppb, discharge levels from the air stripper (without carbon bed) were less than 0.5ppb, representing an overall stripper efficiency of greater than 99.9 percent. As expected activated carbon bed adsorbers reliably reduced chlorinated organic discharges to undetectable levels.

Long-term success of the groundwater remediation program is pending extended operation of the water extraction and treatment program. Continuous operation over a 12 to 18 month period is expected to reduce subsurface contamination below hazardous levels.

Table 7: SUMMARY

- o Comprehensive Hydrogeologic Study Established Groundwater Remediation Program

- o Groundwater Cleanup Program Included:

  -- Tank/ Soil Excavation and Disposal

  -- Multiple Extraction Wells with Interconnecting Trenches

  -- On-site Treatment By Air Strippers and Carbon Beds

- o Success of Remediation Program Awaiting Extended Operation

2500

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